SPECIMENS, &c.

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SOME

SPECIMENS OF A WORK

ON THE

PRINCIPLES OF CHEMISTRY,

WITH OTHER

TREATISES.

BY

EMANUEL SWEDENBORG,

LATE MEMBER OF THE HOUSE OF NOBLES IN THE ROYAL DIET OF SWEDEN,
ASSESSOR OF THE ROYAL METALLIC COLLEGE OF SWEDEN,
FELLOW OF THE ROYAL ACADEMY OF SCIENCES OF UPSALA, AND OF THE ROYAL ACADEMY OF SCIENCES OF STOCKHOLM,
CORRESPONDING MEMBER OF THE IMPERIAL ACADEMY OF SCIENCES OF ST. PETERSBURG.

TRANSLATED FROM THE LATIN

BY

CHARLES EDWARD STRUTT,

MEMBER OF THE ROYAL COLLEGE OF SURGEONS OF EDINBURGH.

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TO THE

BARON JACOB BERZELIUS,

PERPETUAL SECRETARY OF THE ROYAL ACADEMY OF SCIENCES OF STOCKHOLM,

WHOSE FAME AS A CHEMIST IS AS WIDE AS THE CIVILIZED WORLD,

THIS WORK,

THE YOUTHFUL PRODUCTION OF A FORMER MEMBER OF THAT ILLUSTRIOUS ACADEMY,

AND NOW FIRST TRANSLATED INTO ENGLISH,

IS, BY PERMISSION, DEDICATED,

IN HUMBLE ACKNOWLEDGMENT OF HIS UNIFORM URBANITY AND LIBERAL ASSISTANCE,

BY

THE SWEDENBORG ASSOCIATION.

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INTRODUCTION BY THE TRANSLATOR.

The volume now presented to the reader, is a translation of three small treatises in Latin, first published at Amsterdam in 1721. The first of these treatises is a specimen of a new theory for explaining chemical phenomena on geometrical principles; it forms part of a work still existing in manuscript in Sweden, but which has not yet been published. It does not appear to have gone through a second edition, but fresh title pages were used, as some copies bear the date of 1721, others of 1727, whilst others are published at Hilburghausen, in 1754.

The second treatise is a short disquisition on Iron and Fire; with observations and theoretical suggestions, based on actual data obtained at a large iron foundry. It contains many curious remarks, particularly on the laws observed by fire in penetrating hard substances. There are also some ingenious experiments performed by our author on this subject, which are recorded in an essay in the *Miscellaneous Observations.*

The information derived from the iron foundry as to the nature and properties of fire, is reduced to practice in the paper on the construction of stoves. In these new stoves, the object has been to obtain a pleasant and equable temperature, with a constant supply of fresh warm air at the least possible expense of fuel. On this subject also there are several remarks and suggestions in the *Miscellaneous Observations.*

The treatise on the Longitude was first published at Amsterdam in 1721. Like the preceding works, it was furnished with fresh title pages; but a second edition was printed about the year 1766, as we learn from a letter of Swedenborg to Dr. Menander, Archbishop of Sweden. The object has been

to furnish an easy method for sailors to find the longitude at sea; and after examining all the methods then known, Swedenborg decides, that those only are likely to be of use, which are based on the difference of clocks, or on lunar observations. The former has since been effected by the very great improvements in chronometers; and it was to provide against the difficulties of the latter, that Swedenborg proposed his new method. We must leave its practical value at present to the professed astronomer, but the following extract from the letter to Dr. Menander will shew the opinion in which it was held during the last century.

"Most Reverend Doctor, &c.

"I have the pleasure of sending you a small work which I published in my youth, on a new method of finding the longitude, both by sea and by land, by lunar observations; a work which has just been republished at Amsterdam, and which has been submitted to the examination of the learned societies and academies. You will greatly oblige by forwarding a copy of it to the Professor of Astronomy at Abo, in order that if he find this method suited to his genius and worthy of his application, he may put it in practice. In foreign countries, several persons at present employ this method of calculating the ephemerides by pairs of stars, and a great advantage has already been experienced from those which have been made for some years past."*

The new method of constructing docks, in seas where there are no tides, gives us an interesting account of a difficult undertaking, and is a good specimen of Swedenborg's abilities as an engineer. Unfortunately, the plates which illustrated the description do not exist in any of the copies of the work which the translator has been able to procure; but the whole process is so clearly set forth, that the reader will have no difficulty in understanding it, notwithstanding the absence of the illustrations. The plates belonging to the plan for making dams are also lost; but it is hoped that a copy containing them may yet be met with. The volume concludes with a few suggestions for ascertaining the sailing and other qualities of vessels, by expe-

* Dr. Tafel's *Sammlung von Urkunden betreffend das Leben und den Character Emanuel Swedenborg's:* translated by the Rev. J. H. Smithson. p. 226.

riments on a small scale, with a view to their application to ship-building.

The typographical execution of the original work, and particularly of the chemical specimens, is not so creditable to the Dutch printers as the generality of their productions, usually so famed for accuracy. Many misprints occur in the calculations; and in particular, one error at page 3 of the original Latin, influencces a great number of the subsequent results. Great care, however, has been bestowed in correcting them; and consequently, in many instances, the theoretical views coincide more completely with the results obtained by experiments. In several difficult passages, the translator has had the advantage of the coöperation of Mr. J. J. G. Wilkinson, to whom he is likewise indebted for many valuable suggestions throughout the work. The plates and tcxt also have been diligently revised, and the translator hopes that if he has not succeeded in removing all the errors, he has at least rendered the progress of the reader less laborious than it would otherwise have been.

It would be desirable to give a succinct account of the Chcmical Theory of Swedenborg; but as the sketch, or specimen, does not comprize the beginning of the work, we are not in possession of the whole of our author's views, and consequently our description must necessarily be imperfect.

The sketch now before us begins at Part VIII., and is continued to Part XIV.; after which a short appendix on Colours intervenes, and Part XXV. closes this specimen.

The theory of the various subjects treated in this work is deduced from first principles, tested and confirmed by the best experiments of the time. But these experiments were not carried on with that accuracy and minute attention which have characterized the researches of modern chemists; the extensive field of pneumatic chemistry was almost totally unknown, and the careful analyses of so many substances were not then even commenced. Nevertheless, the various experiments of the elder chemists have not been without their uses, as they have led to the more brilliant discoveries of modern times; and we have alluded to their general inferiority merely with a view towards inducing the reader to correct a few errors and misapprehensions into which our author has, from this cause, been led.

Thus, in Part XXV., an experiment of Boyle is mentioned, respecting the calcination of lead, which to the modern chemist will at once appear imperfect. Four ounces of lead are stated to gain only thirteen grains on calcination; but the operation was not complete, owing to the mode in which it was performed by Boyle. Having introduced four ounces of lead into a small glass retort with a long neck, he drew out the orifice till it was only as large as a pin's head; the metal was then kept melted over the fire for two hours. The small orifice was then hermetically sealed, and the lead was kept melted for two hours longer, when part of it was found to be calcined, and to have gained thirteen grains in weight.* It is needless to quote other errors of a similar nature, as they do not affect the general outline of the theory, which was not considered by its author as completely established in all points. In short, he modestly calls his views, new *attempts* towards a mathematical explanation of chemical and physical facts. The valuable part of the theory will remain, and derive additional strength from more recent and correct data, whilst the faulty will be amended; for, like our author, we should constantly make truth our end and aim.

In the beginning of the last century, chemistry was in a state of transition, from the vague, though patient and laborious researches of the alchemists, towards the commencement of the views of the modern school. The science possessed no uniform and definite nomenclature, nor indeed was this possible, as no comprehensive theory had yet arisen; the doctrines of the alchemists, though in many respects mistrusted, were not yet entirely overthrown, and their opinions on the nature of bodies were considered to contain a large portion of truth, concealed in the mystery of their abstruse and frequently unintelligible phraseology.

The doctrine of the four elements, as derived from the ancients, held "divided empire" with that of the three principles of the alchemists; and although signs of decay were evident in these prevailing theories, by the general confusion of ideas as to the manner and proportions in which they were

* Boyle's Works, 4to. London, 1772. Vol. iii., p. 721. See also Lémery's *Cours de Chimie*, Paris, 1756, particularly on Lead, p. 111, and on the Distillation of Salt, p. 445.

combined, accurate experiments were still wanting to throw clearer light on the subject. We must, therefore, take a rapid glance of the meaning which was attached to these terms, and in so doing, we shall select the learned Hiærne as our principal guide.

The doctrine of the four elements is of very ancient date. Thales imagined that water was the beginning of all things; an honour which Anaximenes thought more justly due to air; whilst Heraclitus, of Ephesus, considered fire as the grand principle and element, as both force and matter. Empedocles, however, is generally supposed to have originated the idea of the four elements of earth, water, air, and fire, from which all other things proceeded. And here we must guard against the erroneous impression so generally entertained as to the signification of these terms. These bodies were supposed by the old philosophers to be very subtle and extremely simple substances, produced from chaos by the Creator for the formation of all other bodies. In our world, they are not to be found in a pure and simple state; but they are constantly joined in intimate, though varying, combinations. Thus the earth is not simply terreous matter, but it is united with the other elements, and changed in a thousand ways. In like manner, the water is not, nor can it ever be, free from admixture with the other elements: much less can the air and ether, exposed, as the former is, to the innumerable exhalations from the earth, and the latter to the influence of the sun and other heavenly bodies.

Instead, therefore, of considering *earth* as the soil on which we tread, and which is composed of a multitude of things, the older chemists defined it as the most fixed, firm, and dense of the elements, by itself dry and dead, white in colour, and forming small scales or grains of inconceivable minuteness. It gave consistence to all bodies, together with a power of retaining the other elements. The nearest approach which could be made towards obtaining it in a state of purity was by calcining bones or wood ashes for a long time.

Water was viewed as the cold and humid element, intermediate between earth and air, between the dense and subtle. Its particles were supposed to be vermiform, cylindrical and flexible.

In a state of purity, it would speedily evaporate, as it would be far more subtle and penetrating than ordinary water, which was held to contain a considerable quantity of earth, besides air and fire.

Air was defined as a very subtle, light, and compressible element, filling all things, full of vivifying virtue, the cause of various changes, the medium by which the solar fire flows down to, or into, sublunary objects, and the cause of sound. It was considered in a double point of view: 1. As ether, filling all things between the sun, earth, moon, and other planets, and impregnating their particles with various effluvia and influences. In this state, Van Helmont calls it *magnale*. 2. This ether, filled with various aqueous and terrestrial exhalations, became air. It has gravity as ether, but more as air.

Fire was called the noblest of the elements; compared to the others, it was entirely spiritual, or even, in a certain sense, divine and living. It is a most subtle, quick, and penetrating *ens*, and always in motion, unless when compressed by too narrow bonds: owing to its exceedingly penetrating nature, it fills everything,—the heavens, the bodies of the planets, the air, ocean, and most inward abysses of the earth. Hence the saying, *Nihil igni vacuum esse*. It is the matter of light, and issues from the sun, whence it is dispersed throughout the world, vivifying, illuminating, and penetrating all things in it. Zoroaster and Heraclitus called it the soul of the world, and indeed many of the ancients confounded it with the Deity.

These definitions will shew how widely different were the ideas respecting the four elements entertained by the old philosophers, from those generally ascribed to them. They clearly perceived that ordinary earth was a very compound body, widely differing from their ideal element. They considered water and air in a similar light, and so far were they from confounding their elemental fire with the gross fire produced by combustion, that they expressly state the latter as containing a number of other substances, whilst the former was regarded as scarcely material, but rather as the medium between the material and the immaterial. In fact, their elemental fire appears to have been equivalent to the modern caloric, which no chemist of our times would for a moment maintain as identical with visible fire.

It seems indeed more just to believe, that under the name of these four elements, the older chemists signified those properties of matter on which their evident quality depends. Thus by earth, the solidity existing in various degrees in all bodies, seems to have been implied, whilst water, air, and fire, represented their more interior nature, influence, and life. And this idea may derive additional confirmation from the opinions of the alchemists, that these elements, in varying proportions, constituted the three universal principles—salt, sulphur, and mercury, of which they believed all bodies were formed. As these terms are occasionally used in the work before us, we may be excused for saying a few words on the sense in which they are to be understood.

By *salt,* the ancient chemists did not intend common salt, but that principle which gave their saline character to all the salts then known. It was supposed to be a combination of the elemental earth, water and fire, and to exist as a foundation in all saline substances. In like manner, the *universal sulphur* and *mercury* were peculiar combinations of the primary elements; and by the union of these three general principles in various manners, the metals and other bodies were produced. By some of the alchemists, a fourth principle, arsenic, was admitted, under the name of a *spirit;* a term which they seem also to have applied to all volatile substances.

We may see the origin of these ideas in the results afforded by metallurgic operations. The sulphurous and arsenical exhalations, together with the various saline and earthy substances exhibited during the calcination and reduction of ores, would easily lead the alchemists to consider the metals as compounded of them likewise, and hence the steps to the notion of the transmutation of metals were easy.

The history of the alchemists will teach us the importance of correct theory, and the endless confusion to which erroneous views will lead. We cannot for a moment attempt to defend the alchemists in their notions of the philosopher's stone, the universal panacea, the grand alkahest, and other similar mysteries. The transmutation of metals, however, was a correct deduction from the incorrect opinions of that time, and accordingly, at least in this respect, the alchemists were not altogether

so visionary a race as is generally supposed. Indeed, they would have agreed with the moderns in their assertion of the impossibility of changing what was not gold into that noble metal,—for as Geber justly remarks, "a body cannot possibly yield any substance except that which exists in it." But as they contemplated the metals as compound bodies, they did not perceive any greater absurdity in endeavouring to produce them by chemical means, than in effecting other chemical combinations, which must have appeared to them as equally wonderful and inexplicable. For as Geber again says, in his treatise, *De Investigatione Magisterii,* "to pretend to extract a substance from that which does not contain it, is absurd. But as all metals are formed of mercury and sulphur, more or less pure, we may add to them that which is wanting, or deprive them of what is in excess,"—and this they endeavoured to effect by the usual chemical processes.*

Such were the prevailing views on the foundations of chemistry; and it was in this state of uncertainty that Swedenborg propounded his theory, in accordance with those general laws which he afterwards published in the *Principia,* thirteen years after the publication of this sketch. Before proceeding to consider its merits, we must take a rapid survey of the ideas entertained respecting the atomic theory—as our author's doctrine of matter and its formation differs essentially from those maintained in more recent times, and approaches in some degree to the idea held by the ancients.

The first traces of the atomic theory are ascribed to Leucippus, who flourished about 430 years before the Christian era. He combatted the unsatisfactory notions of the Eleatic school of philosophy, respecting the infinite existence of matter, and advanced an opinion that it consisted of exceedingly small, solid, and impenetrable particles, with a vacuum or empty space existing between them. He considered that these particles differed in figure, to which he ascribed the differences observed in various kinds of matter: he also asserted that the same particles, arranged in another order, would produce bodies of

* In an essay in the *Miscellaneous Observations,* Swedenborg produces several reasons why transmutation cannot be effected.

totally different qualities. Democritus of Abdera held the same opinions, and he called these particles *atoms.*

These atoms were supposed to possess figure and magnitude. Epicurus added a third property, viz., gravity.

These ancient ideas are in many respects the same as those entertained by Swedenborg; but on comparing them with the doctrines of the modern schools, we quickly find a most important distinction, that the atoms of the ancients were simply atoms of *matter,* and identical in their nature, as their properties depended on forms; whilst the atoms of the moderns are considered as atoms of *elements,* and essentially different, according to the nature of each element, that is to say: the ancients considered that the atoms of matter constituted all other bodies, the atoms remaining identical themselves, and occasioning the various qualities of different bodies by their varying and varied arrangements; whereas the moderns consider that there is an essential difference in the first nature of their elementary atoms. In short, the ancients would have viewed the atom of the moderns as a compound body; and such indeed is the view which our author advocates.

This theory of matter is the earliest and most rational with which we are acquainted. By considering the primary matter as possessing extension, solidity, and gravity, it renders the corporeal world intelligible, and satisfactorily accounts for the secondary qualities of bodies. Although Aristotle entertained the idea that matter was homogeneous, but its form various,* yet his extraordinary views of matter and form, as existing independently of each other, caused this ancient theory to remain in the shade for many centuries. Nevertheless the original simple and grand idea has gradually emerged from its obscurity, and has been supported by Des Cartes, Newton, Locke, and other distinguished men.

"It seems probable to me," says Sir Isaac Newton, "that God in the beginning formed matter in solid, massy, hard, impenetrable, moveable particles; of such sizes and figures, and with such other properties, and in such proportion to space,

* "Επειδὴ δὲ ἡ Φὺσις διχῶς, τό τε ἔιδος κὰι ἥ ὕλη," Aristotelis *Naturalis Auscultationis*, lib. ii., p. 465, Paris, 1654, folio.

as most conduced to the end for which he formed them; and that those primitive particles, being solids, are incomparably harder than any porous body compounded of them, even so very hard as never to wear or break in pieces; no ordinary power being able to divide what God himself made one in the first creation. While the particles continue entire, they may compose bodies of one and the same nature and texture in all ages, but should they wear away or break in pieces, the nature of things depending on them would be changed." (*Optics*, book III.)

Swedenborg, in his *Principia*, gives us his ideas respecting the formation of matter, and the nature of the forces by which its particles act on each other, and these we shall shortly describe hereafter. In the mean time, let us consider the views proposed by Newton, in order that we may see the points of resemblance and of difference between the two doctrines. Newton offers the following suggestions in his *Optics* (book III., query 31): "Have not the small particles of bodies certain powers, virtues, or forces, by which they act at a distance, not only upon the rays of light for reflecting, refracting, and inflecting them, but also upon one another, for producing a great part of the phenomena of nature? For it is well known that bodies act one upon another by the attractions of gravity, magnetism, and electricity; and these instances shew the tenor and course of nature, and make it not improbable but that there may be more attractive powers than these. For nature is very consonant to herself. How these attractions may be performed I do not here consider. What I call attraction may be performed by impulse, or by some other means unknown to me..... The attractions of gravity, magnetism, and electricity reach to very sensible distances, and so have been observed by vulgar eyes; and there may be others which reach to so small distances, as hitherto escape observation; and perhaps electrical attraction may reach to such small distances, even without being excited by friction." Newton then proceeds to say, that as the variety of motion which we find in the world is always decreasing, there is a necessity for conserving and recruiting it by active principles, such as the cause of gravity, &c. "These principles I consider not as occult qualities, supposed to result

from the specific forms of things, but as general laws of nature, by which the things themselves are formed; their truth appearing to us by phenomena, though their causes be not yet discovered. For these are manifest qualities, and their causes only are occult. And the Aristotelians gave the name of occult qualities, not to manifest qualities, but to such qualities only as they supposed to lie hid in bodies, and to be the unknown causes of manifest effects. . . . Such occult properties put a stop to the improvement of natural philosophy, and therefore of late years have been rejected. To tell us that every species of things is endowed with an occult specific quality by which it acts, and produces manifest effects, is to tell us nothing." *(Optics,* book III., pp. 260, 261.)

In the philosophy of Swedenborg, we shall see that several of these *occult qualities,* or causes, are explained in a satisfactory manner; for although at a certain point the operations of nature elude the investigation of our senses, we can still judge of causes from their effects; and by reasoning, and testing the truth of our deductions by experiments, we may obtain reasons for believing a theory to be correct, as satisfactory and conclusive as ocular demonstration.

Although the theory proposed by Swedenborg appears to have fallen into oblivion, several chemists have arrived at conclusions similar to some parts of his theoretical views, though no one has again sketched out so great and comprehensive a plan. Thus, Wenzel considered that the properties of bodies depend on the configuration of their smallest particles.* M. Dumas, one of the first chemists of France, or of Europe, coincides with our author as to the compound nature of atoms; in his *Leçons sur la Philosophie Chimique,* he says, "My conviction is, that the equivalents of chemists, those of Wenzel, of Mitscherlich, those which we call *atoms,* are nothing more than molecular groups. If I had the power, I would expunge the word *atom* from the vocabulary of the science, fully persuaded that it goes farther than experiment, and never in chemistry should we go farther than experiment."

* "Die Eigenschaften der Körper von der Figur ihrer kleinsten Theile abhängen." Wenzel, *Lehre von der Verwandschaft der Körper.* Dresden, 1777.

Dalton, to whom the modern atomic theory is so greatly indebted, considers the atoms of substances as differing in their original composition, and as being surrounded individually with atmospheres of heat. This heat he considers as "an elastic fluid of great subtlety, the particles of which repel one another, but are attracted by all other bodies." In his opinion, gases and elastic fluids consist of exceedingly small central atoms of solid matter, which are surrounded by atmospheres of heat, of great density next the atoms, but gradually growing rarer according to some power of the distance; whilst "a solid body is one, the particles of which are in a state of equilibrium betwixt two great powers, attraction and repulsion, but in such a manner that no change can be made in their distances without considerable force. If an approximation of the particles is attempted by force, then the heat resists it; if a separation, then the attraction resists it. . . . The essential distinction between liquids and solids perhaps consists in this, that heat changes the figure of arrangement of the ultimate particles of the former continually and gradually, whilst they retain their liquid form; whereas in the latter it is probable that change of temperature does no more than change the size, and not the arrangement of the ultimate particles. . . . Though the metallic atoms, with their atmospheres of heat, are nearly the same as the atoms of water and their atmospheres, yet it seems highly probable that the metallic atoms, abstracted from their atmospheres, are much larger than those of water in like circumstances. The former, I conceive, are large particles with highly condensed atmospheres; the latter are small particles with more extensive atmospheres, because of their less powerful attraction for heat. Hence it may be supposed the opacity of metals and their lustre are occasioned. A great quantity of solid matter and a high condensation of heat are likely to obstruct the passage of light, and to reflect it." *(New System of Chemical Philosophy.* Manchester, 1808.)

Dalton does not ascribe the qualities of these atoms to their geometrical forms; he considers all the primary elemental particles as spherical, but that in crystallization they produce various forms, according to their various arrangements. Thus, "The rhomboidal form may arise from the proper position of

four, six, eight or nine globular particles; the cubic form from eight particles; the triangular form from three, six, or ten particles; the hexahedral prism from seven particles, &c. Perhaps in due time we may be enabled to ascertain the number and order of elementary particles constituting any given compound element, and from that determine the figure it will prefer on crystallization, and *vice versâ;* but it seems premature to form any theory on this subject, till we have discovered, from other principles, the number and order of the primary elements which combine to form some of the compound elements of most frequent occurrence." *(Ibid.,* p. 210.)

These views of Dalton on the formation of the particles of compound elements have some general points of agreement with those of Swedenborg. The geometrical theory of our author likewise coincides with the opinion of Sir Humphrey Davy, that the phenomena of chemistry "would ultimately be referred to mathematical laws, similar to those which La Place had so profoundly and successfully established with respect to the mechanical properties of matter." He also considered that the elements "consist of points, possessing weight and attractive and repulsive powers; and composing, according to the circumstances of their arrangements, either spherules, or regular solids, and capable of assuming either one form or the other. All that is necessary for the doctrines of the corpuscular philosophy, is to suppose the molecules which we are not able to decompose spherical molecules, and that by the arrangement of spherical molecules regular solids are formed, and that the molecules have certain attractive and repulsive powers which correspond to negative and positive electricity. . . . This is not mere supposition unsupported by experiments; there are various facts which give probability to the idea. The *first fact* is, that all bodies are capable of being rendered fluid by a certain degree of heat, which supposes a freedom of motion in their particles that cannot be well explained except by supposing them spherical in the fluid state. The *second fact* is, that all bodies on becoming solid are capable of assuming regular polyhedral forms. The *third fact* is, that all crystalline bodies present regular electrical poles. And the *fourth fact* is, that the elements of bodies are capable

of being separated from each other by certain electrical attractions and repulsions."

These quotations will suffice to give us a general outline of the atomic theory, as held at present. Yet it is rather viewed as a very useful than as a probable theory; that is to say, whilst the proportional quantities afforded are of great practical benefit, the theory which regards the atoms as solid indivisible particles kept at a distance from each other by some unknown force, is opposed by several chemists of celebrity. Faraday has raised some objections, grounded on electrical phenomena, to which, on the ordinary theories, it would be very difficult to reply. And the opinion that the so-called elementary substances can only be considered as simple bodies, not because they really are simple, but because we are unable to decompose their constituent principles, is very extensively maintained; and several substances, as nitrogen for instance, are now supposed to be compounds.

The great faults of the chemical philosophy of the present day are, the neglect of the finer and subtler agents, such as light, heat, magnetism, &c.; too great reliance on the accumulation of individual facts, instead of the formation of general principles, and not attending sufficiently to the geometrical effects of the forms of substances. The result of this state of science is clearly shewn in the want of a good theory, to explain the facts of which we have at present so vast an abundance. The denial of the existence of the ether and the finer atmospheres, simply because they elude the investigation of our senses, is highly unphilosophical, and either leads us to admit greater difficulties than those which it endeavours to avoid, or leaves us in a state of uncertainty and ignorance, from which we find it impossible to escape. The neglect of the mathematical forms of the ultimate particles in the modern atomic theory is surprising; for as all the advocates of this theory necessarily admit that these atoms have a definite form, we cannot perceive why the same globular shape should be assigned to all of them, nor why, if such be really the case, their qualities should be so essentially different. To surmount this difficulty, a number of properties must be admitted, which if not

actually called *occult*, yet approach too nearly to escape the censure passed on them by Sir Isaac Newton. The mathematical powers and forces of form do not depend upon size, for the properties of a sphere exist as much in the minutest globular atom, as in the sun itself, and consequently we cannot suppose that they exert no influence in the arrangement and mutual action of ultimate particles.

The researches of the modern chemists have been directed towards the acquisition of particular facts; a correct knowledge of which is indispensable to our theoretical reasoning. In this branch of enquiry we are, indeed, well provided with exact data by the labours of the modern chemists, and especially by those of the distinguished Berzelius: but unless we are also guided in our views by general principles, we do not make much real progress in science. We must rather consider our present stores as the foundation whereon to raise theoretical principles, which, when once constructed by some skilful hand, will greatly aid and facilitate our advance. Thus, in the sketch of the theory left us by Swedenborg, we find a doctrine of atomic proportions, as well as of solution, crystallization, decomposition, and other effects clearly traced; and although the instances mentioned may not be found quite exact, they are as well devised in theory as the state of experimental knowledge at the commencement of the last century would allow. Let us, however, hope that the fundamental idea in this sketch may be fully developed by our chemists; for if Swedenborg was astonished that no general principles had been formed, notwithstanding the number of facts ascertained in his time, what would be his surprise at the same want still existing, whilst the number of particular data has been so vastly increased, and so accurately verified! But, indeed, we cannot arrive at any general view by the mere accumulation of individual facts; unless we ascend higher ground, we cannot embrace them as a whole; for whilst we remain amongst them, we seem to be in the midst of a sandy desert, in which the same uniformity prevails, the same want of distinctive feature, the same absence of vegetation; travel in whatever direction we may.

But since truth is universal, we must bear in mind the connexion existing between the sciences, which are its natural

branches. We must not, therefore, overlook the laws which regulate other sciences, and in neglecting them, endeavour to solve the mysteries of chemistry by entirely different principles alone. In this respect the old chemists greatly erred, both by their ignorance of these laws, and by their fanciful and unphilosophical chemical views. The rigid methods of investigation pursued in modern times have had a very beneficial result in demolishing these erroneous ideas, as well as in affording solid materials for the future construction of the edifice of scientific truth. And although in the downfall of the old theories many true notions have for a time been overwhelmed in the ruins, we need not have any apprehension that they will be permanently lost to us. In due time, they will again emerge from their temporary tomb, and, like the phœnix, shine in renewed strength and beauty. What is obscure in one age, is rendered clear by the discoveries of the next. The progress of science is ever onward, and its future career may still be described in the eloquent language of Seneca, whilst the numerous and brilliant discoveries of late years bear witness to the truth of his remarks: "A time will come when, by the growth of ages and the steady march of human diligence, what is now concealed, may be brought into the light of day. A time will come when our descendants will wonder that we were ignorant of what is so plain to them. Much is reserved for future ages, when we shall be forgotten. Nature, as manifested in the world, does not display all her secrets at once. We fancy that we are amongst the initiated, whilst in fact we are detained in the vestibule of her temple. Her mysteries are not revealed indiscriminately to all, but she keeps them in her inner sanctuary."*

The theory proposed by Swedenborg differs very essentially from many of the views quoted above. He considers that the qualities of substances depend upon their forms and motions, all of which proceed in orderly series and degrees, and conse-

* "Veniet tempus, quo ista, quæ nunc latent, in lucem dies extrahat, et longioris ævi diligentia. . . . Veniet tempus, quo posteri nostri tam aperta nos nescisse mirentur. . . . Multa sæculis tunc futuris, quum memoria nostri exoleverit, reservantur. . . . Rerum natura sacra sua non simul tradit. Initiatos nos credimus; in vestibulo ejus hæremus. Illa arcana non promiscue, nec omnibus patent; reducta et interiore sacrario clausa sunt." *Naturalium Quæstionum*, lib. vii.; 25, 31.

quently that matter does not consist of simple and homogeneous particles or atoms, but is highly compounded. And as in his theory, creation proceeds by orderly degrees and series from the simpler to the more compound, the latter contains the powers and qualities of the former, modified by the fresh circumstances in which the simpler principles exist. Thus, as an elementary particle is formed by active finites, which possess an innate tendency to motion, it also preserves a tendency to motion, which is displayed when the circumstances in which it is placed permit. This is the inmost quality of the various particles, but they likewise possess a second kind of qualities, depending on their geometrical forms. In the finer elementary particles, the first kind of qualities which depend on motion are by far the most active; but as we descend towards the denser and grosser forms of matter, we find that the secondary or mathematical qualities, depending on the forms of the particles, preponderate, whilst the former are diminished, and at length are no longer perceptible. Accordingly, in saline bodies, the phenomena of solution, crystallization, and various chemical actions, are satisfactorily explained as necessary results of the shape of the particles; the malleability and other properties of metals likewise are set in clear light by the same reasoning. Nevertheless a complete knowledge cannot be obtained of the denser matter, unless the elementary principles be kept in view also. On this subject, Swedenborg speaks very distinctly in the Preface to the Treatise on Iron in the Mineral Kingdom. Having mentioned the plan on which he proposes to treat his subject, he adds, "It was my wish, besides the foregoing, to give at the end, in a fourth or last division, a theoretical treatise on the several metals, and by principles obtained from experiments, to elicit the use of each. There is, however, so very close a connexion and affinity between all kinds of metals, and likewise between sulphurs, salts and stones, that the quality and texture of the one cannot be discovered, or thoroughly seen, without a simultaneous view of those of the other also. The mutual embracing of these substances is close indeed. Thus in the bosom of metals there lies a sulphurous, stony, and saline component; besides which each metal is tethered in close bonds to every other. The consequence is, that experiments instituted upon one kind of metal

are nowise sufficient to determine its character, unless we bring to bear also phenomena from the other and kindred metals, and from sulphurs of all kinds, &c., &c. Nor is it possible to gain admission to the knowledge of hard bodies, such as metals, in short, to the subterranean and mineral kingdom, unless the elemental world be known to us on the ground of principles, or *a priori*, and unless ether, air, fire, water, and the other elements of the world, be thoroughly investigated. In a word, without a previous explanation of the nature of the elements, it is of no use for the chemist to toil in exploring the character of any of the solids. For this reason, I must waive the theoretical division which I had intended to append to each volume. I think it will be better to collect all such matters into a separate treatise."

Of the necessity of this knowledge of the subtler principles, we shall have abundant proof in the *Specimens* now before us. Let us, therefore, take a rapid survey of our author's Theory of the Creation, which will throw much light on the subject before us.

Notwithstanding the metaphysical subtleties in which the question has been enveloped by the advocates of the German school, it is perfectly clear, to all persons of ordinary comprehension, that the material universe could not have been created from *nothing*; in their opinion, the old adage, *Ex nihilo nihil fit*, is a truth fully admitted. Swedenborg considers the material universe as being the manifestation of the Divine Love and Wisdom in ultimates, and accordingly that it must have proceeded in regular order by progressive series from the Infinite to the finite; from the immaterial to the material. The nature of the Infinite can never be comprehended by the finite; the perfections of the Creator must for ever remain far beyond the limited powers of man; and consequently the works of the Creator, proceeding as they do from the Infinite, must have something of the nature of the Infinite, which renders it impossible for man to obtain a perfect acquaintance with them. Thus, on examining the starry universe, the astronomer is lost in wonder; the suns and systems which he views with the naked eye, vast as they are, and apparently innumerable, he finds to be only a very small part of the heavens, compared to those which are revealed to him by optical instruments; and

every improvement in science only shews more plainly the utter impossibility of acquiring an intimate knowledge of the whole. Nor does it appear more probable that the eye will ever be able to arrive at the boundaries of nature in the minutest researches; every additional power of the microscope proves more and more the inexhaustible variety and infinite complexity of forms, and reveals to us innumerable series of orderly arrangement in bodies, of which, were our unassisted vision our sole means of knowledge, we could not possibly form any conception. As therefore our senses are insufficient, we must rely on our higher faculties; and as we cannot view the wonders of creation *a priori*, we must endeavour to ascend *a posteriori*, and thus form principles, which, being in harmony with the phenomena that come under the cognizance of our senses, will guide us through those that surpass their perception. But in following this plan, many difficulties arise to obstruct our progress. For, whilst man remains in this state of existence, and is clothed with a material body, somewhat of a material idea attends all his thoughts, and prevents him from forming very clear or just notions as to the nature of that which is immaterial; and consequently, as in tracing the past order and series through which the world has passed to its present beautiful and varied condition, we must always come to the transition to the immaterial, since it is from the immaterial and infinite alone that the material and finite can have proceeded, we shall have to keep this truth before us. When the sciences shall have been brought to a proper state, we shall find that what is obscure and difficult in one branch, may be enlightened and explained by a science of a higher order, and thus that much in the material world, which at first appears confused or inexplicable, may be placed in its proper position, as being above the apprehension of man whilst in this lower sphere. For in this regular series and order of creation, what we call matter is only the commencement of the lower forms, which become perceptible to our material senses. The more gross and dense the matter, the more readily are we convinced of its existence, and the more easily can we investigate its more obvious qualities. But we also find, that in the same proportion its active powers decrease; and that as we ascend in the scale, whilst the qualities understood by the term

matter gradually diminish, those respecting motion and activity increase, until we soon arrive at a state in which the existing forces have been divested of what, to our senses, are material properties. Here, then, instead of denying that there are any powers of this high quality, because our senses are too material to apprehend them, we should study them in their effects; and thus by our reasoning faculties, we shall be able to obtain some insight into the producing causes. Bearing this view of the subject in mind, we shall find that the theory submitted by Swedenborg is the most satisfactory which has yet been suggested.

The first peculiarity that strikes us in this system, is the uniformity of forces and laws which regulate the universe; the development of the same powers which formed a single particle of matter, having produced the whole planetary system. Indeed the latter may be considered as an elementary particle on a large scale, as an atom of the universe. Thus in both we find passives and actives, or motive forces which are the primary means of the production of matter.

The natural point is the same as the geometrical point, the beginning of nature is identical with that of geometry. It is a medium between the Infinite and the finite; and consequently, when considered *a priori*, is beyond our comprehension, but viewed *a posteriori*, it is the first means in creation. It is produced immediately from the Infinite, and is pure and total motion, which being beyond geometry, cannot be conceived of according to any of its laws: a spiral force is, however, the nearest analogical idea we can form of it. These points, by mutually finiting or limiting each other, constitute the first *finite*, which being thus derived from motion, preserves a tendency to motion, and provided there be space for its career, it describes a certain spiral curve, and thus passes into an active state, or, as our author says, it becomes an *active*. The second finite is produced in a similar manner from the first, the third from the second, and so on up to the fifth. These finites, when in a sufficiently free space, yield to their internal motion, and become actives. An *element* consists of spherical particles containing actives in the interior, and passives on the surface. Of these elements, Swedenborg reckons five; the *first* element is

the cause of gravity; it fills the whole space of the starry heavens, and forms the solar vortex: the *second* is the magnetic element: the *third* is the ether: the *fourth* is the air: and the *fifth* is the aqueous vapour. Of fire and water we shall speak presently. The limits of a preface will not permit us to enter very largely into the manner of the formation and properties of these different elements, for which we must refer the reader to the *Principia*, where they are treated at length; our object being rather to shew our author's idea respecting matter, as compared with the views entertained previously. We will endeavour, therefore, briefly to point out these differences.

In Swedenborg's theory, the formative power, or motion, acts from the centre towards the periphery; and each particle, from the first finited, has a motion of the parts composing its surface, a rotation round its axis, and a local motion through space. It also has poles, an equator, an ecliptic, and meridians, and is, according to its state of activity, a representation of the sun or earth on a small scale. The point, by its spiral motion, generates the first finite; the first finite generates the second finite; the first elementary particle, which is the particle of the solar vortex, is produced from the passives which form its crust, and the actives which fill its interior. Then was the sun formed, and consisted of these first and second finites in a state of activity, (or *actives)* which filled its interior, and of a crust of finites reduced to a passive state. Near the solar space, the first elementary particles became greatly compressed, and formed the third finites, which constitute the crust of the second, or magnetic element. The particles of this magnetic element, by compression, formed a passive boundary of fourth finites round the solar space: and as this crust was formed in motion, it continued to gyrate round its active centre. Owing to the centrifugal force, this crust became attenuated, and at length burst; its fragments forming planets and satellites of various dimensions. This is the chaos of the ancients, in which they believed that all things were confused together. But the work of creation was not yet complete; the earth did not exhibit any variety, it consisted merely of a globe of these fourth finites, containing a portion of the actives in its centre. Thus launched from the

sun into space, the earth still obeyed the general law of spiral motion, and consequently its earlier revolutions round the sun were far more rapid than those in subsequent times, and thus it passed through an innumerable variety of changes. Near the sun, the pressure of the solar vortex is too great to allow the fourth finites, of which the earth is composed, to assume an active state; but as the distance increases, this pressure diminishes, and accordingly the finites on the surface of the earth have freer space, and passing into active motion, begin to form particles of ether. These particles are bullular, they consist of the fourth finites on the surface, and of particles of the solar vortical element in the interior. Thus we arrive at the third element, which may be called, as far as our sensual perceptions extend, the beginning of matter; or rather let us say, that in the state of ether, matter has become sufficiently gross to be perceptible to our senses by its effects. It is by the various tremulations and undulations of the ether and its crustal particles that light and heat are produced; light is occasioned by the undulations of the ethereal particles, which act on the eye as the undulations of air act on the ear; whilst heat, that is to say, the subtle elementary fire, is produced by the superficial or crustal particles (the fourth finites) of the ethereal particles in an active state.

But from this state, in which the earth consisted only of one kind of finites, and was clad with only one ethereal atmosphere, innumerable changes must ensue, before it can be furnished with air, water, and the various mineral substances calculated to enable it to bring forth its vegetable treasures. Accordingly, on gaining a greater distance from the sun, the pressure of the solar vortical element having thereby diminished, the fourth finites have sufficient space for becoming active, and thus for constituting the fifth finites. These latter finites form the crust of the particles of air, whilst the interiors are filled with particles of the first and second, or vortical and magnetic elements. The air is similar to the ether in its properties, and only differs in degree and dimensions. Thus as the modulations of the ether produce light, those of the air produce sound; and as the crustal particles of the ether, in an active state, produce the

subtle elementary fire, those of air, in the same condition, cause the ordinary fire and flame, which are of such vast utility in a multitude of operations.

This distinction in the nature of fire explains several phenomena in chemistry and physics which are otherwise inexplicable. The different effects produced by solar and artificial heat are well known, and evidently prove that some essential difference exists in their nature and quality. We may mention one experiment which is conclusive, namely, that glass allows a very large proportion of the solar heat to traverse it, whilst artificial heat is almost entirely arrested. The subtle igneous matter so frequently mentioned in the chemical theory, is, therefore, nothing more than ether, which keeps the particles of fluids at a certain distance from each other, and exists in the pores of solids. In this state it is equivalent to the latent caloric of Dr. Black and other chemists; but when the fourth finites forming the surface of its particles are set at liberty, they pass into the active state, and produce visible effects. The ordinary fire obeys the same laws, except that the particles of air are to be substituted for those of ether, which will produce a corresponding change in the results. The whole theory is detailed at length in the *Principia,* and the mutual influence of bullular particles of different dimensions is considered in an essay in the *Miscellaneous Observations.*

As in so many other particulars, the views of Swedenborg have received confirmation in this respect from the researches of modern philosophers. Sir Humphrey Davy* considers that Dr. Herschel's experiments demonstrate that radiant heat is produced by the undulations of a peculiar substance. "On this theory it has been assumed, 1. That an elastic ethereal medium exists in space. 2. That this medium is diffused through the pores of different ponderable substances, in different states of density. 3. That radiant heat is constituted by particular undulations of it when in a free state. 4. That sensible heat is occasioned by particular undulations of it, in its states of diffusion through the pores of ponderable substances. 5. That certain peculiar vibratory motions of the particles of

* Sir Humphrey Davy's Works, London, 1839, vol. ii., p. 391.

ponderable substances are capable of producing the undulations in the ethereal medium which constitutes heat. 6. And reciprocally, that those undulatory motions of the ethereal medium are capable of producing peculiar vibrations of the particles of ponderable substances. . . . . These propositions are evidently countenanced by the experiments of Count Rumford and Professor Pictet on the heat produced by friction. They are rendered more conclusive by the analogy between the laws of the motions of radiant heat and those of sound. And they, in some measure, reconcile the two different theories," of undulations, and rectilinear projections.

Having thus seen the origin of the fourth element, or air, and of fire, we arrive at the formation of water. The particle of water is a particle of air reduced by compression to a spherule containing contiguous spherules within it. It is consequently no longer elastic, elementary, and yielding, but hard, incapable of becoming active, and therefore is purely material; consequently we cannot consider it as an elementary particle. The method in which the particles of water were produced is described at considerable length in the *Principia*, Part III., Chapter IX., to which we must refer the reader; we may here simply mention that these particles have not an exactly smooth and polished surface, and that they owe their mobility to the ether which permeates between them. The newly-formed water thus overspread the whole earth,

——— sea covered sea,
Sea without shore.

The aqueous vapour is the fifth element of the world, and is similar to the preceding elements, only differing in its degrees and dimensions. Like them, it consists of bullular particles; the particles of water forming the crust, whilst a small volume of ether exists as an active force in the interior. Like the finer elements, it is elastic, though not so completely and rapidly; it is capable of being expanded and compressed, and preserves its spherical form under all varieties of pressure. The aqueous is thus the last of the atmospheres surrounding the earth; and as long as the earth occupies its present position in the solar vortex, no denser can be formed. "Although the last product,

yet as an elementary it is the first perceptible to sight and touch; for if we take a side view of the surface of warm water, we may see subtle vapours arising in a round form, and the surface of the water expending itself, and gradually passing in strata into a new kind of elementary product. Thus in forming her elements, nature terminates where the senses begin; being visible only in her last and ultimate limits, and ending, as it were, where the knowledge of the senses first commences; rendering herself visible to the human eye in order that man may not be ignorant of her qualities. Our sensual organs are material, and can perceive nothing except through the medium of the elements, hence they perceive effects, but not causes; the cause acts in order that the effects may be perceived; hence no elementary can be perceived, except the last, which does not operate any longer upon any of our organs."

We have thus arrived at the last of the general atmospheres surrounding the earth, and we have found a similarity of structure throughout the elements, from the first or most subtle, to the last or densest. Each element presents an outward crust in a passive state, and an internal space in a state of activity; the only differences being in dimension and degree. Owing to these differences, the larger and denser elements are permeable to the finer, and consequently, in some measure, they contain all that has preceded them. Thus, a particle of aqueous vapour contains ether in its interior, and water particles on its crust; the water particles contain all that lie enclosed in the air particles, since they are formed by the latter in a condensed state; every particle of air contains the second element, in every particle of ether there is the first element, and thus we arrive by a regular series up to the point, beyond and above which is the Infinite, the great Creator of all things.

Our planet is now ready for the production of the dry land, which was effected by the changes produced in the extreme depths of this primeval ocean. By the great pressure of the superincumbent waters, the aqueous particles in these lowest parts were disrupted, and the arrangement of the globular particles composing their crust being destroyed, the latter, which in this work are called particles of the fifth dimension, fell into the cubical interstices between the aqueous particles. Similar

causes produced a similar result in the particles of the fifth dimension, which were thereby reduced to those of the fourth dimension, and they again fell into the interstices between their predecessors. We find, therefore, that a great variety might have arisen in the composition, specific gravity, and qualities of various orders of substances thus moulded in these spaces; and this variety would again be vastly increased by the different positions which the spherical particles of water might assume, whereby corresponding changes in the intervening spaces would necessarily be occasioned. The substances formed in this manner, are salts, stones, and rocks of various kinds, according to the forms of their particles. It is here that the subject is taken up in the work before us, and the various phenomena and properties exhibited by bodies traced to their primary form.

We have thus endeavoured to sketch a faint outline of the general theory advanced by Swedenborg on Creation. We have seen that he attributes the essential properties of things to their motion and form. The more exalted their properties, the more transcendent and perfect is their form, and consequently their motion. From the spiral forms of the primary active forces, we pass through the spherical forms of the elements, and descend to the angular forms of the dense and ponderous earthy substances. We can but with difficulty form a clear idea of the activity of the elements, yet we see that each acts with greater energy and rapidity in proportion as it is more subtle. How surprising is the power of steam, but how greatly is it surpassed by the action of heat, light, electricity, and magnetism! Here our senses are bounded in their perceptions, and we have no means of ascertaining the energies of the first acting forces, but we are fully justified in supposing that they must excel those of the elements, as the latter excel those of the angular, inert and lifeless terrestrial matter. And by the same analogy, how far superior to his outward body must be that internal organization of man, by which he is enabled to receive life and intelligence from the Supreme Being, who is the only source of every good!

It appears, therefore, that the views of Swedenborg concerning matter differ very considerably from those entertained by philosophers at the present day. Whilst the latter consider

matter as being formed instantaneously out of nothing, and that as many different kinds of matter were created as there are elements, or rather as there are substances incapable of being reduced by human art to simpler arrangements, Swedenborg considers that it passed through orderly series of changes from the immaterial, becoming gradually more and more material, more and more gross, until at length its qualities, that is to say, a few of its more evident and outward qualities, come under the cognizance of our senses. In his system, geometry reigns throughout, and if we cannot as yet follow clearly in every direction, it is owing to the immense variety continually increasing as we proceed. In his views, matter assumes a far greater plasticity, as well as a far greater complexity, than is at all possible when it is considered as merely consisting of hard, impenetrable atoms; a theory which is found so unsatisfactory, that occult forces and powers acting at a distance are obliged to be added, to explain the phenomena of nature, notwithstanding the difficulty attending the conception of a force, in itself considered as not any distinct existence, acting through a vacuum or space in which there is nothing to act upon. Our author's system, however, is free from such objections; it shews us a regular series of cause and effect throughout the whole. The *atom* or simple, also, has a very different signification, since it is not applied to a particle incapable of further division, but to the least division of a substance possessing the same qualities; not that it cannot be subdivided, but that in thereby losing its peculiar form, it would lose the qualities which it then possessed, and acquire those of another series. Thus a particle of lead is considered a simple, because it is the smallest division to which we can conceive lead to be reduced without destroying its properties, depending on its form; and not because incapable of further subdivision, since it is shewn to be a very complex body, containing thirteen globes and six cubes, but were they separated from each other, they would assume new properties. These views coincide in many respects with those of the more ancient philosophers, which were the remains of a better state of knowledge, and which, in the opinion of many, have fallen into unmerited neglect and oblivion. For although they rea-

soned too exclusively from first principles, for which they did not possess sufficient data, and did not pay sufficient attention to the experimental sources of knowledge, which would have supplied this deficiency, yet it is not so certain that the views of the moderns are in a much more satisfactory condition; since they appear to have quitted the consideration of first principles altogether, and to rely merely on experimental philosophy, without attempting to deduce therefrom any system generally applicable to the whole circle of the sciences. Experiments are useful, both in affording us the groundwork on which to erect the theory of general principles, and also in testing the truth of our deductions; but by confining ourselves exclusively to their consideration, we shall never be able to arrive at any general views.

The relative states of astronomy and chemistry afford us a convincing proof of the mutual importance of correct experiments and observations, and of correct theory; for although in the former science, the theory only refers to the motions of the heavenly bodies, and does not offer any explanation as to the causes and origin of these motions, yet being based on observation, and correct as far as it goes, it enables us to foretell with certainty, from theory alone, the various changes and appearances shewn by the heavenly bodies; and the coincidence of the predictions with actual observation clearly proves the correctness of the theory. But in chemistry, how widely different is the case! Notwithstanding the multitude of experimental facts, we are as yet almost completely in the dark as to what can be considered as the causes of action; and in all probability must continue to remain so, until some master mind arise to combine all these scattered and discordant facts, and to explain the apparent incongruities by a true theory. But before we can hope to attain this step, we must follow the same course which has been followed in astronomy; we must first ascertain the laws of action in the finer and subtler elements, which doubtless exercise a far more important influence in chemical phenomena than is at present even suspected; then, by applying them to our experiments, and reasoning from them, we shall be able to found a correct theory, in the same way as in

astronomy, an accurate knowledge of the laws of motion has led to such important results. The knowledge of the chemical laws, depending on the finer elements, is however far more difficult to attain than that of the laws of motion; but although experiments may not prove so useful in assisting us to obtain our end, for which we must rely principally on reason and geometry, yet they will prove of vast importance in enabling us to test the accuracy of our conclusions.

And it is not too much to hope, that in time we shall be able to discover the laws which these finer elements obey; already many facts can be satisfactorily explained by the theory of which a sketch is now submitted to the reader; the undulatory theory of light, now so generally admitted, is a remarkable confirmation of our author's views; the distinctions which he establishes in the nature of fire, shew us the reason of the different effects produced by solar heat, and common fire; whilst his theory on magnetism appears to be the most ingenious and explicit yet proposed. These subjects, however, are treated at considerable length in the *Principia*, to which the reader is referred. In the introduction to that work, by the translator, the Rev. A. Clissold, the reader will find an able summary of the views of our author, as contrasted with those of the scientific world; and in the *Miscellaneous Observations*, there are several highly curious essays on the nature of the bullular particles constituting the elements. These works, however, only refer to the inanimate realms of nature; but in the *Animal Kingdom* and in the *Economy*, the subject is pursued through a higher sphere; till at last, in the *Worship and Love of God*, we arrive at the highest subject which philosophy is capable of investigating,—the nature of the human soul, and the wisdom and power of our Almighty Father, as shewn in its formation. Let us also endeavour so to improve our knowledge, that, whilst paying that honour to scientific philosophy to which its great uses so justly entitle it, we may always bear in mind that it is only the stepping-stone to the higher knowledge of ourselves, our nature, duties, and destinies, and from thence to the true love and worship of God, the Great Father of all, and the only Giver of all good. When this unity of scientific and religious truth shall be effected, then, but not till then, may we hope to

see some of the evils and misfortunes by which humanity is at present so oppressed, effectually removed and corrected; to this result all knowledge tends, or, to use Lord Bacon's forcible language, it tends to the glory of God, and the improvement of man's estate.

SPECIMENS

OF A WORK,

ON THE

PRINCIPLES OF NATURAL PHILOSOPHY,

COMPRISING

NEW ATTEMPTS TO EXPLAIN THE PHENOMENA OF CHEMISTRY AND PHYSICS BY GEOMETRY.

THE ORIGINAL FIRST PUBLISHED AT AMSTERDAM IN 1721.

TO THE READER.

The reader will be equally astonished with myself, that the knowledge of invisibles has remained hidden from the learned world up to the present time, when so many experiments respecting them are on record. If we look to Physics, we shall find that it abounds in experiments and discoveries! More light has been shed upon it in the way of experiment during the last century, than in any previous age; indeed, so far as facts are concerned, it has reached a meridian degree of brightness. If we consider Chemistry, with what experiments is it not enriched! So greatly has it exercised the industry of the learned, that we possess thousands of guides towards penetrating its secrets. If Geometry, to what a height has it not been carried by the men of science of our time! It seems indeed to have scaled the sacred hill, and for all human purposes, to have attained the utmost perfection. If, therefore, a thousand signs indicate one thing, we must suppose, as the subject is purely geometrical, that it may eventually be discovered and demonstrated. For what are Physics and Chemistry? What is their nature, if not *a peculiar mechanism?* What is there new in nature, *which is not geometrical?* What is the variety of experiments, but a variety of *position, figure, weight,* and *motion* in particles? Since then we have several thousand experiments, indicating the nature of the various metals, salts, and elements; and since these bodies entirely consist of groups

of particles, varying in their shapes and positions; in which, again, there is a certain geometrical arrangement; we have grounds for concluding that these subjects may at last be demonstrated. To this end, I have collected experiments from the best authorities, as Boyle, my own countryman Hjærne, Boerhaave, Lemmer, and others, which I have added to and partly repeated; I have also applied geometry to the investigation of causes, and have at length formed principles in accordance with my data. It is for the reader to judge of what I have done, and may it meet with his approbation.

In the work itself, I intend to shew the theory of the other metals, salts and elements, according to the same connexion and order. In this Prodromus I present only a specimen.

ON THE FIRST GENERATION OF SALTS, ETC., IN THE PRIMEVAL OCEAN, WITH A FEW REMARKS ON THE DEPTH OF THAT OCEAN.

In opposition to the theory that common salt and the other solids originate in water, and in fact from the breaking up of its particles at the bottom of the sea, it may be objected that salts are not only found in the ocean and other waters, but also on land; for there are whole mountains of salt; there are salts in herbs and vegetables, in the soil, and even in the stones themselves, whence they may be extracted by calcination. This seems to militate against my theory of the origin of salts at the bottom of the ocean and between the particles of water; but I shall obviate this objection by shewing, in a Treatise on the Depth of the Primeval Ocean, and that, too, by numerous and convincing proofs, that a primeval sea once stood at an immense height above the surface of our present land; that in the lapse of time it subsided to the level of our land and ocean; and that the soil on which we now dwell was formerly the bottom of a sea, in which mountains of salt and stone, as well as all saline compounds, originated.

The fact of a primeval ocean having stood at a great height above the present land, is more clearly deducible from the surface of northern than of southern countries. In the former there is obviously a kind of impression of the sea on almost every sod; the land everywhere presents the greatest inequalities, now rising into mountains and hills, now sinking into valleys, sometimes scooped and channelled for lakes and rivers, at others rugged with heaps and masses of stones, or divided

by ridges of sand, pebbles, and shingle, extending from twenty to thirty miles. Large quantities of tortoise and various other shells are imbedded in the highest mountains, in such abundance, that the inhabitants burn them for lime, which is sold in all the surrounding districts. Moreover, the most different strata may be seen in the ground and in the mountains; for instance, in quarries, in the shelvings of the loftier hills, and in all rocky situations: figured stones, petrified animalculæ and fishes, are met with in the layers; also, the skin and ribs of a huge whale were found in a district full twelve miles from the sea; and even in the rocks, there are caverns of the most exact roundness, as if polished by the ebb and flow of water, and the action of stones; besides many other traces of a primeval ocean which are most visibly and deeply imprinted on the soil.

In this northern region, whole provinces are covered with stones of immense size and weight; these stones lie in plains, valleys, lakes, and the deepest beds of rivers; on the highest mountains, and even on their summits; in ridges and beds of sand; or deeply hidden, and entombed in the earth: some of them weigh 100,000 Dutch pounds, as may fairly be concluded from their size; and what is still more wonderful, one stone is often placed on two or three others; all which things are monuments of a deep ocean, the bottom of which was the ground we now inhabit.

In the Treatise on the Ocean, it is my intention to shew, that stones of immense weight were tossed about, and carried over the globe at the bottom of a deep and rolling sea. This may be inferred from the following facts of hydrostatics, and from the nature of water,—1. Stone weighs, to its volume of water, nearly as $2\frac{1}{2}$ to 1. 2. To salt water, somewhat less. 3. And in water it loses almost half its weight, so that there remains $2\frac{1}{2}—1=1\frac{1}{2}$. 4. Hence the weight of stone is not felt in the same degree in the sea as in the air; the aqueous element being so heavy, as nearly to equal the remainder of the weight; that is, the weight of stone in water being to water as $1\frac{1}{2}$ to 1, in air it will be to air as 2,000 to 1. 5. If waves act at the bottom of the sea as tempests act at the bottom of the atmosphere, on the habitable ground; and if the column of sea be

some hundreds of fathoms in depth, the motion and force of the rolling water must be increased at the bottom in proportion to the depths and bases; so that a wave, when continued towards the bottom, would by its depth exert a greater force than on the surface. 6. Consequently, the primeval sea had sufficient force to loosen huge stones from the mountains, to carry them with it, to scatter them here and there over the earth, and even to disturb its whole foundation. 7. Just as the atmosphere on land acts upon wood, bark, leaves, feathers, rags, and, near the shore, on large drifts of sand, and on many other substances a thousand times heavier than itself. For when the air is disturbed by a storm, these things are caught up and carried aloft as if they were lighter than itself;—an effect seemingly owing both to the increased areas of divided bodies, and to the height of the atmosphere, which once set in action, imparts, by the weight of its column, a power to the tempest similar to the force of a large body in motion. 8. Many examples of this fact are seen in sea dykes and embankments, constructed of double rows of piles and heaps of stones. When the water rises three or four yards, as during the spring tides, it often exerts a force sufficient to overturn the embankment, carrying the stones headlong with it, and transporting them sometimes to the distance of a hundred feet, which is entirely owing to the depth of the wave. 9. Hence, in some northern countries, the fragments of rock, in places far above our sea, are larger and more numerous than elsewhere, for they might be driven thither by the following waves, but not higher, because they would be nearer to the surface.

Seeing, then, that a deep sea could move such enormous masses of stone, and consequently its very foundations, from their places, it follows, that the surface of the present land owes its unevenness to the ocean; and that all the mingled accumulations of mud, sand, shells, and stones, were produced by the motion of the waves at its bottom. Hence—1. Hills of so many kinds and forms. 2. So many strata therein. 3. So many mountain-ridges, partly consisting of sand, partly of large stones, extending from ten to thirty miles, surrounded also by sloping mounds, and other signs of the sea washing up the materials of its bed into heaps. 4. And what principally con-

firms these views is, that, *firstly,* the backs of the ridges generally extend from north to south, which seems to have been occasioned by prevailing easterly and westerly winds, such as now exist in the great ocean; for such winds there necessarily were in this continuous, diluvian, northern ocean, when it was without a shore. *Secondly,* there is a rotundity in the very pebbles of which immense ridges are composed, and which are also often buried in the sand at a depth of twenty or thirty yards; they look as if they were turned and polished,—a sign that they have been tossed about, and have suffered attrition from a constant rolling motion at the bottom of the sea. *Thirdly,* marks of this very sea are apparent about the ridges, on which certain horizontal lines and divisions are even now visible, &c., &c. 6. *Hence the origin of salt mountains; hence the inward cohesion of the solid matters at the bottom of the ocean,* as advanced in my *Principles.**

The circumstances here mentioned may have been produced by a deluge, but it may perhaps be doubted whether they all could have happened in Noah's Deluge, which only lasted a single year. What renders it doubtful, is, that at this day, the timbers and ribs of vessels and galleys have been discovered in places which are now forty or fifty yards above the level of the sea, and that hooks, rings, and hawsers, with many other indications of a port and of inhabitants have been found even on the mountains: and it is certain that the Baltic is still gradually subsiding towards the north, at a rate of four or five yards in depth in less than seventy years; so that, in many localities, within the last hundred years, the plough has supplanted the oar, and the sower taken the place of the fisherman. I myself have seen these marine spots, and have heard old men conversing about them. In Lapland, at the extremity of the Gulf of Bothnia, within a century, towns have undergone a spontaneous removal from the shore, and are now some thousand paces distant from the original site of their port; and similar things have happened to other places on the same coast; which may serve

* The author does not here appear to refer to his work *The Principia,* but to a manuscript treatise, of which the present work is a part, and which exists in the Library of the Royal Academy of Sciences of Stockholm. The title *Principles* has therefore been adopted, to avoid misleading the reader.—*Translator.*

to prove, that all these circumstances were not occasioned by the universal Deluge, but that, for a long time afterwards, the northern countries especially, lay under a deep ocean, and that as the sea gradually subsided towards the north, they emerged and formed a habitable land.

Should this view be established by the future discoveries of scientific men, it will furnish a reason for thinking, although not for positively asserting,—1. That even the horizontal pressure is liable to change; which follows if, according to the allowed opinion, the seas be depressed towards the north, and elevated towards the equator. 2. And, consequently, that the distances of the latitudes vary between the poles. 3. That certain countries in the far north, agreeably to the notion of modern, as well as to the accounts of ancient authors, may once have been islands, which, in process of time, as the sea subsided, united into a continent or contiguous land. Besides these, there are many other things, which I shall not venture to publish, until I am strengthened by still more numerous proofs, and enabled to proceed on a firmer foundation.

If, then, an ancient ocean stood at such an altitude above the earth, and if the dry land owe its form, and, in a certain sense, its origin, to this parent, it may surely be concluded, that salt mountains must have originated at its bottom, as well as rocks and all the solid matters composed of saline particles; which particles are set free by calcination, crystallization, and other chemical processes; respecting which I would refer the reader to my *Principles.*

PRINCIPLES OF NATURAL PHILOSOPHY.

PART VIII.

ON THE DIFFERENT POSITIONS OF ROUND PARTICLES.

1. *The vertical position.*

The position is vertical, when the particles are arranged in such a manner that one rests upon the top of another, as in Figure 1 (Plate I.), where their centres form a kind of regular cube. Spherical particles appear to be placed in this position:—1. When they are in the most rapid motion, that is, when they are driven round centrally; because if the particles or their planes be moved centrally, there will be no contact except in a single point, which here will be at the top. For four toothed wheels may be moved round their centres when in a square position, but not when arranged in the triangular. 2. Likewise when they are erected from a compact position to a looser one, by a matter flowing between them. 3. Also when particles of a cubic form are intermingled amongst the round particles; such are the particles in Figure 2, which will be repeatedly mentioned in the Theory of Salts and Metals.

If eight centres be placed together, so as to form a regular cube, we obtain the space of a cube; then, if the semi-diameter of a globule be equal to d, the line between two centres will be equal to $2d$, which is the diameter of the cube; the cube produced from that line $= 2d \times 2d \times 2d$; any one of the solid angles in it occupies one eighth part of a whole globule, and as there are eight angles, they occupy the space of a whole globule, which in the same limits is equal to $\frac{88d^3}{21}$; whence by computation the ratio of the spaces may be obtained. It is clear,

FIG. 1.

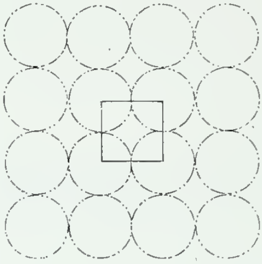


FIG. 2

FIG. 4.

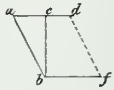


FIG. 5

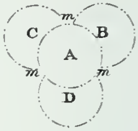


FIG. 6.

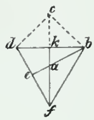


FIG. 3.

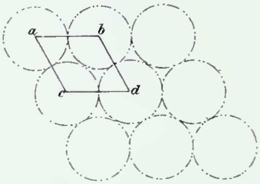


FIG. 7.

FIG. 8.

FIG. 10.

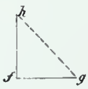


FIG. 9.

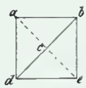


FIG. 11.

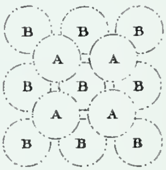


FIG. 12.

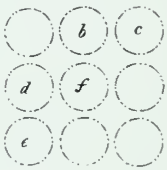


FIG. 13.

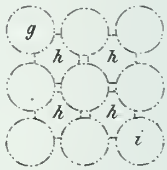


FIG. 15.

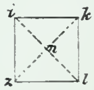


FIG. 16.

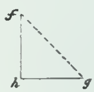


FIG. 14.

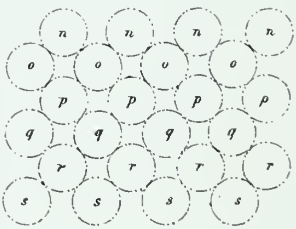
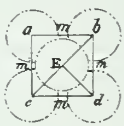


FIG. 17.



therefore, 1. That the whole volume or total space is to the space which the globules occupy, as $8d^3$ is to $\frac{88d^3}{21}$, or as 21 to 11. 2. That the whole volume is to the intermediate space between the globules (which in the following pages we shall call the *empty space,)* as 21 to 10, which is a necessary consequence from the preceding. 3. That the space which the globules occupy (which in the following pages we shall designate as the *full space,)* is to the intermediate space, or the full space is to the empty space, as 11 to 10.

2. *The triangular position of the first kind.*

The triangular position of the first kind occurs when the particles are arranged in a triangular position at the base, but in the vertical position from thence upwards, as in Figure 3, which represents the base of the particles. We think that the particles may assume this position ; 1. When the central motion of the planes is continued, whilst the motion of the particles in the vertical plane ceases. 2. When certain triangular and four-sided figures are interposed, as will frequently be seen in the Theories of Salts and Metals. 3. The horizontal plane in this situation is shewn in Figure 3, but the vertical plane and the oblique plane at 45°, in Figure 1.

If now, one plane describes a parallelogram, and ab and bf (Figure 4) pass through the points of contact, ad will be equal to $2d$; let the perpendicular bc fall on the side ad, the following result will evidently take place ; $(ab)^2-(ac)^2=(bc)^2$, or $4d^2-d^2=3d^2=(bc)^2$, therefore $bc=d\sqrt{3}=\frac{7d}{4}$ nearly. Hence by multiplication, the parallelogram or base will be obtained, which will give $2d\times 2d\times\frac{7d}{4}=7d^3$ for the whole volume. The rest may be obtained by calculation. 1. The space of the volume is to the full space as $7d^3$ is to $\frac{88d^3}{21}$, or as 147 to 88 nearly. 2. The space of the volume is to the empty space as 147 to 59 nearly. 3. The full space is to the empty space as 88 to 59. 4. The vertical position is to this position as $\frac{21}{11}$ to $\frac{147}{88}$, or as 8

to 7. 5. The fixed quadrilateral pyramidal position is to this position as $\frac{147}{110}$ is to $\frac{147}{88}$, or as 4 to 5.

3. *The triangular position of the second kind.*

This position takes place when the vertical plane of the particles is similar in its arrangement to the horizontal plane delineated in Fig. 3 and 4. We think that the particles are arranged in this position: 1. When the axillary motion ceases in either plane, which may happen by the evolution and separation of the subtle igneous matter, or by a certain pressure of the particles. 2. The particles may be brought into this position by the triangles, so often mentioned in the Theory of Salts and Metals. 3. We shall also see in the Theory of Water, that its particles assume this position when they pass into the state of ice. 4. The horizontal plane is similar to that shewn in Figure 3, and the vertical plane is the same as the horizontal; so that wherever a particle may be, it rests upon two others.

As in this position the vertical plane forms a parallelogram, the space of its volume will $=2d\times\sqrt{3}d\times\sqrt{3}d=6d^3$. Hence,

1. The space of the volume is to the full space as $6d^3$ to $\frac{88d^3}{21}$ or as 63 to 44.

2. The space of the volume is to the empty space as 63 to 19.

3. The full space is to the empty space as 44 to 19.

4. The vertical position is to this position as $\frac{21}{11}$ to $\frac{63}{44}$, or as 4 to 3.

5. The triangular position of the first kind is to this position as $\frac{147}{88}$ to $\frac{63}{44}$, or as 7 to 6.

4. *The triangular position of the third kind.*

This position of round particles ensues when the three planes are parallelograms; the space is obtained by multiplying $\sqrt{3}d\times\sqrt{3}d\times\sqrt{3}d=3\sqrt{3}d^3=\frac{21d^3}{4}$, whence,

1. The space of the volume is to the full space as $\frac{21d^3}{4}$ to $\frac{88d^3}{21}$, or as 441 to 352, which is very nearly as 5 to 4.

2. The space of the volume is to the empty space as 441 to 89, or very nearly as 5 to 1.

3. The full space is to the empty space as 352 to 89, or nearly as 4 to 1.

4. The vertical position is to this position as $\frac{21}{11}$ to $\frac{441}{352}$, or as 32 to 21.

5. *The fixed triangular pyramidal position.*

When one globule lies upon three others, that is, upon the interval of these three, we call the position the fixed triangular pyramidal. We think that particles may naturally assume this arrangement; 1. By the utmost rest and cold, and by the greatest superincumbent weight. 2. By the intermixture of certain kinds of triangles, which will be mentioned in the Theory of Salts. 3. Here the horizontal plane is like Figure 5, where A rests upon the three globules, C, B, D.

Let the semi-diameter $= d$. In Figure 6, d, b, f, are the centres of three globules, and c is the centre of the upper one; $cb = 2d$, because it passes through the point of contact. The base of that triangle (ab or af) may be obtained by the proportion of the sides, $be : bf :: ef : af$, or $\sqrt{3}d$ is to $2d$ as d is to $\frac{2d^2}{\sqrt{3}d}$, whence we derive that $ab = \frac{2d}{\sqrt{3}}$; then $(ca)^2 = (bc)^2 - (ab)^2 = 4d^2 - \frac{64d^2}{49} = \frac{132d^2}{49}$, the root of which is $\frac{23d}{14}$; hence the rest by multiplication, $2d \times \frac{7d}{4} \times \frac{23d}{14} = \frac{23d^3}{4}$; consequently we derive,

1. The space of the volume is to the full space as $\frac{23d^3}{4}$ to $\frac{88d^3}{21}$, or as 483 to 352, or very nearly as 11 to 8.

2. The space of the volume is to the empty space as 483 to 131, or nearly as 11 to 3.

3. The full space is to the empty space as 352 to 131, or nearly as 8 to 3.

6. *The fluid triangular pyramidal position.*

When the particles, instead of touching each other, are

separated by equal spaces, the position is called the fluid triangular pyramidal, as in Fig. 7, where the upper globule lies also on three others. We think that the particles may assume this position: 1. When they are brought to a certain fluidity from the fixed triangular of the second kind. 2. When they are brought from the natural into a less compact or dense fluid, &c.

Let the arrangement be as in the preceding triangle, Fig. 6, $df=2x$; then $dk=x$, and $kf=\frac{7x}{4}$, af may be obtained by proportion, $kf : df :: ef : af$; or $\frac{7x}{4} : 2x :: x : \frac{8x}{7}$: that the height ac may be obtained, fa is the base, ac the perpendicular, the hypothenuse$=2d$; $fa=\frac{8x}{7}$, ac according to the rule$=x$, hence $\frac{64x^2}{49}+x^2=\frac{113x^2}{49}=4d^2$, or $\frac{53x}{35}=2d$, or $x=\frac{4d}{3}$; now substitute $\frac{4d}{3}$ instead of x, by the same calculation we shall obtain $\frac{8d}{3}\times\frac{7d}{3}\times\frac{4d}{3}=\frac{224d^3}{27}$. Hence,

1. The space of the volume is to the full space as $\frac{224d^3}{27}$ is to $\frac{88d^3}{21}$, or as 196 to 99.
2. The whole space is to the empty space as 196 to 97.
3. The full space is to the empty space as 99 to 97.

7. *The fixed quadrilateral pyramidal position.*

When one globule rests upon four others, the position is called the fixed quadrilateral pyramidal. This arrangement is extremely close, and we think that particles may assume it, 1, when they are subjected to very great pressure, equal in the lateral and vertical directions. 2. Likewise when intermixed with the cubic forms continually mentioned in the Theory of Salts and Metals. 3. When the particles of water are in extremely deep situations. 4. The horizontal plane is shewn in Figure 1, or 8, and the vertical is similar; this position is more fully mentioned in the Treatise on the shapes of the interstices of water in the quadrilateral pyramidal position.

If now we join together eight centres, we shall have a cubic parallelogram, as in Fig. 9. The line passing through the points of contact *de* is equal to $2d$: the base to the perpendicular *cd* (or *fg*, Fig. 10) may be obtained by the rectangular triangle *deb;* thus, $(db)^2 = (de)^2 + (eb)^2 = 4d^2 + 4d^2 = 8d^2$, the root of which is nearly equal to $\frac{14d}{5}$, and the half of it, $dc = \frac{7d}{5}$ nearly. The perpendicular *hf* (Fig. 10) is equal to this, and therefore the cubic parallelogram may be obtained by multiplying the sides and the height, thus $2d \times 2d \times \frac{7d}{5} = \frac{28d^3}{5}$. Hence,

1. The space of the volume is to the full space as $\frac{28d^3}{5}$ to $\frac{88d^3}{21}$, or as 147 to 110, nearly as 4 to 3.

2. The space of the volume is to the empty space as 147 to 37, or nearly 4 to 1.

3. The full space is to the empty space as 110 to 37, or nearly 3 to 1.

4. The vertical position is to this position as $\frac{21}{11}$ to $\frac{147}{110}$, or as 10 to 7.

5. This position is to the triangular position of the first kind as $\frac{147}{110}$ to $\frac{147}{88}$, or as 4 to 5.

6. This position is to the triangular position of the second kind as $\frac{147}{110}$ to $\frac{63}{44}$, or as 14 to 15.

8. *The fluid quadrilateral pyramidal or natural position.*

This position takes place when the round particles are arranged according to Figures 11 and 12, where the particles BBBB are in a square position, and equally distant from each other. The upper particles AAA are resting upon, or in the interstices of, the four below them, and they also are equally separated from each other on every side. We think that the particles may assume this arrangement :—1. When the subtle igneous matter flows between them. 2. When they are naturally in a fluid state. 3. We also consider that when the elementary particles and those of solid bodies are liquefied by fire, they take this position. 4. The horizontal plane is shewn in Figures 12 and 13. 5. The vertical plane is precisely similar, (Figures 12

and 13,) which follows thence geometrically. 6. If this plane be intersected diagonally, the section will be like Figure 14, where the particles touch each other mutually by points. 7. If a volume of these particles be cut obliquely, a plane will be obtained exactly similar to the plane in Fig. 14. 8. All the planes in this position are equal. But more will be said of this position in the Theory of the Elements.

Let *abcd* (Figure 17) be the square formed by the centres, and let the lines Ed and Eb pass through the points of contact to the upper centre. According to what has been said above, the distance from the superior to the inferior centre will be equal to the distance mm: let us suppose $bd=2x$, and the semi-diameter$=d$. In the square, (Figure 15,) $kl=2x$, therefore $(nl)^2=2x^2$: nl is the base of the vertical triangle, (Fig 16,) to which let us now proceed. Here the base is $hg=nl$, and its square$=2x^2$; therefore $(fg)^2=3x^2$. As the line fg proceeds from centre to centre through the point of contact, it will be equal to $2d$; hence $(hg)^2+(fh)^2=(fg)^2$; or $3x^2=4d^2$, or the root $\frac{7x}{4}=2d$; that is $x=\frac{8d}{7}$, whence $2x\times 2x\times x=4\times\frac{8d}{7}\times\frac{4d^2}{3}=\frac{128d^3}{21}$. Therefore,

1. The space of the volume is to the full space as $\frac{128d^3}{21}$ to $\frac{88d^3}{21}$, or as 16 to 11.

2. The space of the volume is to the empty space as 16 to 5.

3. The full space is to the empty space as 11 to 5.

4. The vertical position is to this position as 21 to 16.

5. The fixed quadrilateral pyramidal is to this position as 147 to 160, or very nearly as 11 to 12.

6. The triangular position of the first kind is to this position as 147 to 128.

7. The triangular position of the second kind is to this position as 63 to 64.

8. The triangular position of the third kind is to this position as 441 to 512, or nearly as 55 to 64.

9. The fixed triangular pyramidal position is to this position as 483 to 512, or nearly as 17 to 18.

10. The fluid triangular pyramidal is to this position as 49 to 36.

11. The intermediate space or distance m, is $\frac{1}{7}$ of the diameter b.

12. The diameter of the space E between four globules, is to the diameter of a single globule as 3 to 5.*

* The following tables may perhaps assist the reader in comparing the respective weight and bulk of the different positions.

I.

Positions.	Full Space.	Empty Space.	Space of Volume.
Vertical position	100	90·909	190·909
Triangular of the first kind	100	67·045	167·045
Triangular of the second kind	100	43·181	143·181
Triangular of the third kind	100	25·284	125·284
Fixed triangular pyramidal	100	37·216	137·216
Fluid triangular pyramidal	100	97·979	197·979
Fixed quadrilateral pyramidal	100	33·636	133·636
Fluid quadrilateral pyramidal, or *natural*	100	45·454	145·454

II.

Positions.	Space of Vol.	Full Space.	Empty Space.
Vertical position	100	52·381	47·619
Triangular of the first kind	100	59·864	40·136
Triangular of the second kind	100	69·841	30·159
Triangular of the third kind	100	79·818	20·182
Fixed triangular pyramidal	100	72·877	27·123
Fluid triangular pyramidal	100	50·510	49·490
Fixed quadrilateral pyramidal	100	74.830	25·170
Fluid quadrilateral pyramidal, or *natural*	100	68·750	31·250

EXAMPLE.—In Table I., 100 globules arranged in the vertical position will contain a space amongst their intervals = 90·909, and the space of the whole volume will be 190·909: or 100 in weight will measure 190·909 in bulk.

Table II. A volume in the vertical position = 100 will contain 52·381 particles, the space between them being 47·619: or a volume measuring 100 will weigh 52·381. —*Translator.*

PART IX.

THE THEORY OF WATER: BRIEFLY SHEWING THE GEOMETRICAL PROPERTIES AND INTERNAL MECHANISM OF ITS PARTICLES.

1. *Description of the particles of water.*

We think that the particles of water belong to the sixth kind of hard particles. According to our *Principles*, the dimensions of the diameters in the hard particles increase in a tenfold ratio, as in Plate II., Figure 1; where, according to the demonstration in the preceding articles, it may be seen,—1. That the particle of water is round. 2. That on its surface there are crustals of the fifth kind. 3. That again on their surface there are crustals of the fourth kind, and so on to the first kind, and at length to mathematical points, or to atoms composed of points. 4. That all those which are on the surfaces, are hard and of the same nature as the larger particle, that is, as the water itself. 5. In the middle of the particle of water there is a cavity, the space in which is equal to the space of its crustals, or to the space of its superficial parts. 6. In the same way there is a cavity in the particles of the fifth kind, in which the space is equal to the space of its crustals; and so on in particles of whatever dimension. So that according to the demonstrations in Parts II., III. and IV. of our *Principles*, the particles are not only round, but also hollow, and the superficial ones, of whatever kind, are of the same nature as the larger particle. 7. The diameter of a crustal, or superficial particle, is to the diameter of a larger particle as 1 to 10 nearly, which follows from the cavity occupying half the space of the particle; for if the internal cavity is equal to the

FIG. 1.

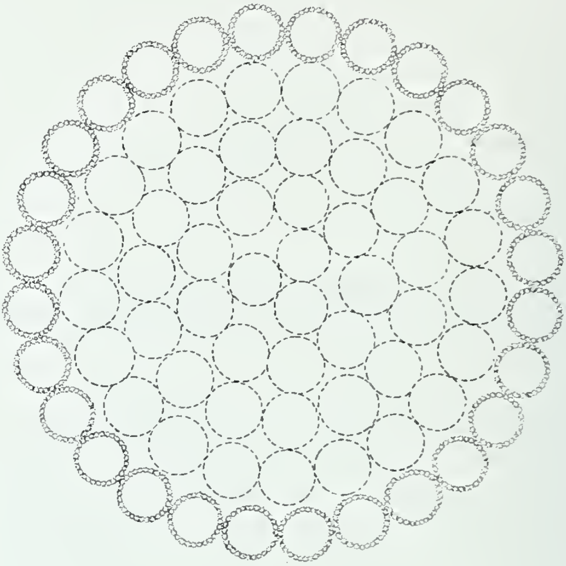


FIG. 3.

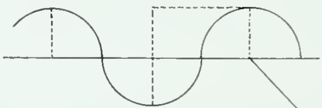
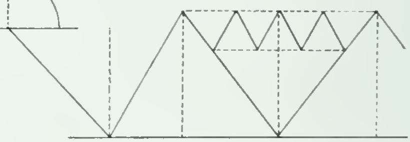


FIG. 4.



space which the crustals occupy, and the diameter of the particle be 10, it follows that the diameter of the cavity will be very nearly 8; for $8 \times 8 \times 8 = 512$; and $10 \times 10 \times 10 = 1000$. 8. It follows from the same principles, that the arrangement of the crustals is triangular; and since they contain a subtle matter, they are moveable in their surface: in the same way the smaller crustals are also moveable in their surface; but for these matters the reader is referred to Parts II., III. and IV. in our *Principles*.

§ 2. *The position of the particles of water.*

Since the particles of water are of a round shape, and their surfaces are occupied by round particles of a smaller kind, similar in nature, but differing in diameter and magnitude; and since, from the nature of fire, its subtle matter penetrates everywhere amongst the interstices of the water, separates one particle from another, and thus gives a certain motion to each; (but when this heat flies off, the particles become spontaneously fixed and crystallized, as will be seen in the Theory of Ice); hence, if the forms of the particles be taken into account, as well as the motion of the subtle fire, it will be clear, that the particles of flowing water are arranged in the natural, or fluid quadrilateral pyramidal position. In Part VIII., § 8, of these *Principles*, this position is described as occurring, 1. When the centres of four particles form a square, or eight of them make a cube. 2. In this position, it follows geometrically, that both the horizontal and vertical planes are in a square arrangement, and that the centres are in right lines. 3. The space between any two particles is equal to one seventh part of the diameter of a globule. 4. The space between an upper and a lower particle is also one seventh of the diameter. 5. The horizontal plane is equal to the vertical, and each of them is equal to the oblique. 6. That this is the natural position of flowing particles, is demonstrated as follows:—*Firstly*. If the position be square, a certain fluidity and central gyration can be given to the particles; for if four toothed wheels be joined together by the mutual insertion of their cogs, they may all move round their centres, and continue their gyrations. But if three of these wheels be connected together, we find that

the motion of one is hindered by that of another, because there is no application of the motion of the third wheel to the first, and thus onwards: whence it is clear, that particles centrally moveable are in the square and natural position. *Secondly.* Since the motion is equal in every part, both laterally and perpendicularly, an equality is obtained in the fluid element through equal distances. *Thirdly.* If the subtle matter be at liberty to flow between the individual particles, it is dilated and compressed according to the apertures and spaces in which it is enclosed, as will be demonstrated in the Theory of Fire; whence, since the aforesaid subtle matter can separate the particles from each other, it will form equal spaces for itself; but a different result takes place amongst particles which it cannot separate. Thus, both the nature of the interfluent matter, and the motion of the particles produce the natural arrangement, in which the particles are at equal distances from each other, &c.

§ 3. *The natural motion of the particles of water.*

Respecting the round figure of the particles of water, and their natural motion, we have to observe, 1. That the particles of water are moved by the subtle igneous matter flowing amongst them, in which, as it were, they float: this result takes place when the fiery element occupies their interstices equally, and separates one particle from another by equal distances. 2. In proportion as the shapes more nearly approach the globular, they can be separated by a smaller quantity of this interposed matter, and with less force. 3. But on the contrary, a greater quantity and more force will be necessary in proportion as the points of contact are more numerous; or as the particles have less rotundity. 4. Hence as the particles of water are round, though covered on the surface by crustals which occasion a certain roughness, they are mutually separable by the smallest stream of subtle matter. 5. The nature of fluidity consists, *firstly,* in every particle being fluid by itself; *secondly,* in the motion being not only central, but local also, so that there is an aptitude in each particle for separating itself from any other; *thirdly,* in the motion of one particle being the motion of another; that is, when one globule is moved, the mass is moved, the

same ratio of motion existing in the mass as in any single particle.

It follows geometrically, that fluidity is chiefly owing to the rotundity of the particles, for as the form becomes rounder, its fitness for fluidity increases. It is to be observed, 1. That round particles touch each other by points only, and thus have the fewest lateral obstacles. 2. The particle is fixed and bound by the points of contact, which in round bodies are at the minimum, and indeed, scarcely exist. 3. In round bodies the radii, semi-diameters, or lines from the centre to the surface are equal, and consequently there are no prominent points or angles to impede motion. 4. Hence it follows, that the round particle can be moved centrally and in its place, which cannot occur in particles of any other shape. For example, if a cube be moved centrally amongst a mass of cubes of the same dimensions, it must first raise up the lateral cubes, or else thrust them on one side; the result will be different with cylinders, or figures of an oval or parabolic shape. 5. Hence also it is clear, that the globular is the very form of motion: for if particles of various kinds be shaken or agitated together, they will at length assume a round shape by their mutual friction and motion, as is the case in hard bodies, and even in stones. 6. Likewise, that to render an element fluid, it is sufficient to cause it to assume rotundity, as happens when fire converts the metals themselves into a fluid glass, or when water is changed into an aeriform volume, or air passes into an aqueous state. 7. Thus roundness is the essential shape of motion, and is motion itself; or rotundity =motion. 8. On this account we think that the particles of all the elements are comparatively round, because they are so highly mobile; some are hard, as water and its crustals: some soft, or bullular, as fire; and others composed of both kinds, as air; these subjects are considered in the *Principles* and Theory of the Elements. 9. The motion of the bullæ and superficial particles is most rapid, owing to the lightness and exceeding smallness of each particle, as well as to their yielding in all directions, and their want of cohesion: but these subjects will be mentioned in their proper places.

§ 4. *The central motion of the particles of water.*

It also necessarily results from the rotundity of the particles, that they possess a central motion, especially since the chief property of fluidity consists in the motion of each particle: but from the rough outline of the shape of the particles of water, it follows, 1. That they would have no central motion, were it not for the subtle igneous matter, described in our Theory of Fire and Light, and which is diffused around each particle. 2. Let us, therefore, assume that subtle matter as the cause of the central motion; hence it follows, *firstly,* that each particle may be driven round its centre, and be moveable in its place. *Secondly,* The central revolution of one particle gives rise to the central motion of those adjoining its sides. *Thirdly,* The particles of a whole plane are driven round centrally; but half of the plane proceeds towards the right, and the other half towards the left. *Fourthly,* In like manner, the particles of a whole vertical plane are driven, half towards the right, and half towards the left, because the vertical plane is similar to the horizontal, and both are in the square position. *Fifthly,* One plane can pass through another, as will be shewn hereafter. But if a central motion be communicated to the globules of water, it must necessarily be owing to the subtle igneous matter, which fills up the interstices equally, and keeps the globules of the denser element floating in its stream.

§ 5. *The local motion of the particles of water.*

From the mechanism of the arrangement of the flowing particles of water in the natural position, it is evident, 1. That by the force of motion, or of pressure, a particle can pass through the interstices existing between the others, and thus change its situation. 2. Also, that one upper particle passes between four beneath it. 3. Or, at the side, one particle passes between four lateral ones, as in Plate II., Fig. 2, and consequently 4 pass between 9, 9 between 16, 16 between 25; and so on, in the quadratic proportion. 4. It also follows from the same construction, that an upper particle cannot pass between four lower ones, unless those which are beneath can pass between the lateral particles, for when one particle endeavours

FIG. 2.

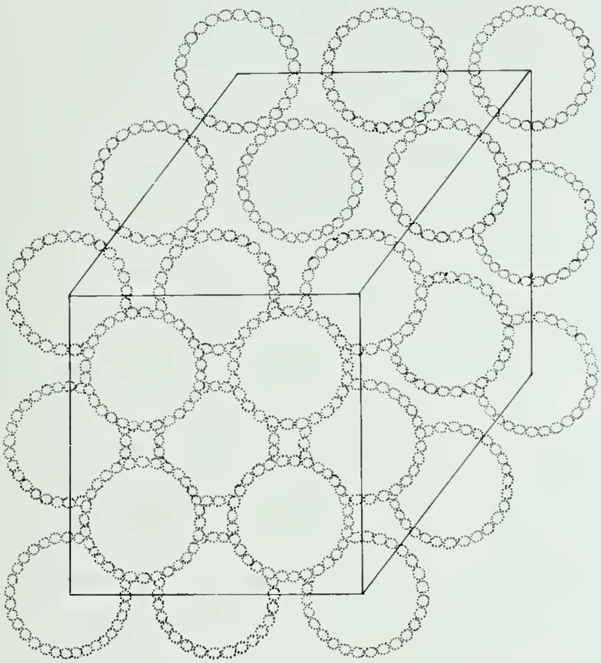
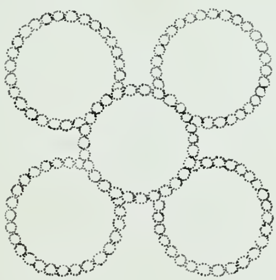


FIG. 2.



to pass between the four under it, the latter are thrust towards the sides as much as they are impelled downwards; consequently no transition of the particles can take place in a right line, either horizontally, or perpendicularly; but it must be obliquely, according to the mechanism of the natural position. 5. Likewise when a particle is about to pass between those on the side, these latter thrust their lateral neighbours towards the sides, as well as upwards and downwards, whereby the pressure or local motion of the particles returns to the surface. 6. Hence we find that the local motion of the particles in the natural position is equal on all sides, and that the motion of one becomes the motion of another, and thus of the volume.

When, therefore, the particles change their position, it follows, 1. That their transition is equal on every side. 2. And occasions a certain undulation on the surface. 3. This undulation, like the local motion of the particles, is equal on every side. 4. The particles can only be raised above the surface, in proportion as they are depressed beneath it: *vide* Plate II., Fig. 3. 5. The breadth, or diameter of any circle, is equal to the depth of the transition of the particle towards the bottom, as is shewn in the same figure. 6. In places of less depth, the waters are raised to a less height above the surface, and smaller circles are produced. 7. Whether the circles be large or small, they pass over equal distances in equal times; *vide* Plate II., Fig. 4. 8. The progression of the diameters is in the simple ratio of the times. 9. This progression is continued from the centre to the periphery, and is again renewed, as in *Ibid.*, Fig. 4. 10. Thus we perceive that the natural undulation of the elements is owing to the mechanism of their shape; and to their position, which is the natural, or fluid quadrilateral pyramidal; and that the result would be different, were the arrangement triangular, or were each particle not moveable in its place. 11. From the same mechanism it follows, that several circles can be formed without confusion in the same sphere from different centres, for whether the surface be raised or depressed by the undulation, yet during the motion, it preserves its nature, to which the transitions of the particles tend. 12. Hence in water, many circles can take place in one sphere; many sounds in the air, and many rays in a more subtle element; for which phe-

nomena, the reader is referred to Part III., treating of the Motion of Round Particles in the Natural Position.

But, if the particles be of another shape, as cylindrical, parabolic, elliptic, flexible, &c., it follows, 1. That the undulations would take place, according to the mechanical form of these particles: in some parts there would be none, in others they would tend towards one spot only, sometimes they would be irregular, and sometimes mutually hinder each other. 2. The changes themselves and the local motions of the particles would be unequal, and not in proportion to their depth.

§ 6. *The pressure of the particles of water.*

It is evident from the local motion, that it and the pressure possess an aptitude for mutually passing into each other, so that both the pressure and the local motion are of the same nature. Hence it follows; 1. That one particle presses four others beneath it, these 4 press 9, and so on, 16, 25, 36, 49, 64, &c. 2. The pressure is the same laterally as towards the bottom, and likewise towards the surface. 3. The pressure of the particles is in a circle, that is to say, it is equal towards every side, like the transition and elevation of the particles; thus the pressure itself is the same as the local motion, or aptitude for transition of the particles.

Hence it follows; 1. That the particles are pressed according to their depth, both downwards, towards the sides, and upwards, so that the pressure of the depth is equal in every direction. 2. The whole volume, according to its depth, is pressed by a single particle, as is shewn in Plate II. Figure 2; that is, 9 are pressed by 4, and 4 by 1, &c., as much laterally as upwards or downwards, so that the whole volume is moved or pressed by the influence of one particle. Hence it follows, *firstly,* that the element is pressed according to its depth: *secondly,* according to the size of the base, and not according to the weight or water in the volume above it: *thirdly,* the surface of water is horizontal, owing to the equal pressure towards every side.

It follows that the velocity of the motion of the particles is according to the pressure of the depth: whence, 1. The velocity is less at a smaller depth, or under a less column. 2. The velocity increases at any depth in the duplicate ratio of the times,

and in the same proportion as projectiles; that is, in the first moment, it is 1, in the next 3, then 5, 7, 9, 11, and so on. 3. Whence also water, thrown up from a fountain, ascends to the same height as its source: but on these topics consult Parts II. III. IV. of our *Principles*.

The nature of the subtle matter may be seen in the Theory of Fire, where also the evaporation of water, or its transformation into vapours, is discussed in paragraph 11. Congelation will be found in the Theory of Ice.

As we have already treated of the motion of round particles, and of their different kinds, both superficial and hard, (see our *Principles*, Parts I. to VIII.,) it is useless to delay much upon these matters at present, or to say more concerning the globules of water than may be necessary to understand the following subjects. We will therefore briefly mention the experiments on the aqueous globules, all of which are demonstrated geometrically in our *Principles*.

1. Water is very fluid, whether any weight press upon it, or not.

2. Water undulates slowly, and forms undulating circles of exact sphericity.

3. The undulating circles reciprocate, that is, they begin again from the centres.

4. Undulations may be larger or smaller, but their diameters pass through equal spaces in equal times.

5. Many undulations can take place in one sphere, but each of them proceeds on its road without interruption.

6. The surface of water, unless it be bounded by narrow limits, is a very exact plane.

7. The pressure of water is everywhere in proportion to its depth.

8. Water presses according to its height and base; that is to say, according to the column from the base to the surface, thus,—

If the vessel be very broad at the bottom, and the column be very narrow above, the water is nevertheless pressed according to the area of the base, by a column equal to the base.

Or if the vessel be narrow at the base, and the column be very wide above it, the water will still be pressed according to the area of the base, and by a column equal to it.

9. If there be an aperture below the water, the pressure will still be equal to the height and orifice of the column, whether the superincumbent mass of fluid be the Ocean, or a stream, or a small pipe of narrow bore.

10. The pressure of water is equal on every side.

If a bladder full of air be plunged into water, it will be equally pressed on every side.

11. Water, issuing from an orifice, rises to the level of its source.

12. Water, flowing through an orifice, acquires as much velocity as would be gained by a body falling through the same height in the same time.

13. So much is to be deducted from the weight of any body in water, as an equal bulk of water would weigh, &c. A ship with all its armament weighs as much in the water, as the bulk of water itself would weigh, which the ship occupies or displaces.

14. Water poured into a narrow orifice will raise the water in a large aperture. Hence a very slender body of water can raise a great weight; according to mechanics.

15. Water can penetrate into pores, into which air cannot enter.

16. Water is equally pressed on every side by the air, nor can it flow into the air unless by the weight of its volume. A drop of water is pressed by the air on every side equally, that is, into a sphere.

17. Water can flow along the under side of an oblique plane without falling into the air; this experiment succeeds at 45°, or according to the velocity of its stream.

18. If the air does not press above, the water cannot possibly fall into it.

19. In curved syphons, the water is driven upwards to the height of about thirty feet, by the pressure of the atmosphere.

20. By evaporation, water rises from the soil and lakes, and its vapours appear to the naked eye like round bullæ.

21. Falling water is converted into foam and bubbles. Water thrown on to fire is also converted into froth and bubbles.

Water converted into foam rises very speedily from the bottom to the surface, and is frequently thrown above it.

Vapours penetrate as far as the region of the clouds, and are

there dissipated; so light is water in a state of expansion: *vide Principles,* Part IV.

The surface of a bulla of water becomes gradually thinner towards the top, where it breaks.

22. If water be poured down into the air, it spreads out into thin surfaces, and at last into bullæ.

When water is precipitated down the shaft of a very deep mine, as at Fhalun, the whole of it (though there be a cask-full) is dispersed into vapours, so that if a person stands at the bottom, he does not perceive a single drop: the height is 200 feet.

23. When the air is full of vapours, the mercury in the barometer sinks, and the column of air is lighter than when the atmosphere is free from them.

24. Water, when thrown into the fire, crepitates and is dispersed.

25. A small drop of water may be so expanded in a retort, as to fill the whole of the vessel.

26. Water when converted into vapour, possesses so much power, that it can move an entire machine like a wheel.

27. If melted iron or copper flow upon a volume of water, the enclosed water becomes so distended, that the fluid metal is thrown up to a height of ten or twenty yards.

28. The particles of water rise spontaneously through the pores of sugar.

29. They also ascend spontaneously through the pores of snow. Also in spongy substances. In woods, through the delicate pores of the filaments. Likewise through the small tubes in herbs and fruits. In stones, and their pores. In metals, as in iron; and they have also been found in gold.

30. Water rises spontaneously into a slender glass tube, above the level of the external water. It rises higher, in proportion as the cavity of the tube is smaller. It rises in the same way, whether the tube be in the vacuum of the air-pump, or in the free atmosphere.

31. Water rises, in a manner spontaneously, between polished planes joined in close apposition, both in a vacuum, and in the open air. This may be seen by placing a piece of blotting paper between the two planes. Water rises though ashes, up to the surface; slowly at first, but still more slowly afterwards, both

in vacuo, and in the open air. If any air be in the ashes, it is expelled by the ascent of the water.

32. Water is converted into ice by cold, especially when in a state of rest, but not otherwise.

When water is changing into ice, it expands by many degrees, and very quickly, until it is entirely congealed. Whilst passing into ice, it expands so powerfully that it will burst a cannon, and raise houses from their foundation. It will break timber and walls, with a crashing sound. It renders iron and other hard bodies brittle.

33. Water converted into ice, becomes lighter, and weighs about one-twentieth part less than its bulk of water.

34. Refrigerated water exhales a great quantity of vapours.

35. In ice, the subtle matter collects into granules and innumerable globules. The subtle matter exists in great abundance in places which appear to be empty, sometimes like stars, at others like streaks, &c., perpendicular to the surface.

36. Water is fixed and crystallized, like germinations, and various kinds of vegetables. Small icy particles have also been observed, concreted together upon the ice, like offshoots, exactly in the form of hexagonal crystals. In congealed water, lines and transverse fissures are visible, mutually intersecting each other at an angle of 60°. Ice breaks in lines perpendicular to the bottom.

37. The forms of snow are extremely various. Some are lamellar, and very light. Some are hexagonal and star-shaped. Some are like buds and branches. Others are like globes. Snow is very light, and easily dissolves into globules of water. If ice be broken or pounded into very small particles, it assumes the appearance of snow.

38. If a liquid be congealed in a phial, and placed in a quantity of water, the ice in the phial will be dissolved and converted into a fluid. Flesh, vegetables, oysters, shell-fish, &c., congealed by ice, can be thawed by fresh water applied externally. Frost-bitten hands and fingers are restored by water. If a stream of water be placed near a bed in a garden, the plants in that bed are less injured by the cold.

39. Water is greatly cooled by some salts, as by sal ammoniac, nitre, the residue of salts, and by metals.

40. If an earthen vessel be filled with snow-water and salt well stirred together, and if there be any water under the vessel, it will be frozen to the table: this will occur even in a hot place.

41. The cold is more intense in the lower than in the upper part of a well, as is proved by letting down phials filled with hot liquid.

42. When water is boiling in a brazen vessel over the fire, the upper part contains more heat than the lower.

43. The froth and bubbles of water are as white as snow. A yellow, red, or other coloured liquid converted into bubbles, likewise becomes white. Ice containing a great quantity of bubbles, is as white as snow. Oil and water well mixed together by heat, become white like milk or snow. Water mixed with highly rectified spirit of wine, turns white.

44. When water is stagnant, it becomes excessively putrid, but not whilst flowing and moving about. Putrid water passes through various colours, from green to red and yellow. The water of the ocean at the equator, becomes putrid during a calm.

45. When water is acted upon by a burning glass, somewhat of an urinous odour is perceived.

46. The most limpid water after a time deposits some tartar, or thick substance at the bottom.

47. The power of water as a menstruum in salts, &c., may be seen in the Theory of Salts, and the nature of reflexion and refraction, in the Theory of Light.

PART X.

THE SHAPES OF THE INTERSTICES OF WATER IN THE FIXED QUADRILATERAL PYRAMIDAL POSITION.

§ 1. *The position of the particles of water at the bottom of the sea.*

Since the subtle igneous matter, set in motion by the solar rays, cannot penetrate into the deepest parts of the sea, it follows; 1. That the fluid or natural position of the particles cannot be preserved at the bottom of the sea, owing to the superincumbent weight, and to the deficiency of the subtle matter. 2. The position of the particles at the bottom of the sea, is the next in order to their natural position; that is, it is the fixed quadrilateral pyramidal, because that arrangement is most nearly allied to the natural and fluid position, as the latter cannot be converted into any other, on account of the weight above it. For if the weight press down from above, and at the same time from below and at the sides, the particles must necessarily be changed from the natural position into the arrangement represented in Plate III., Fig. B.

§ 2. *The disintegration of the particles of water at the bottom of the sea.*

As the theory of the composition of the particles shews that they consist of various orders of crustals, and that the dimensions of the larger and smaller diameters are in a tenfold ratio, it follows; 1. That the hard particles, with the crustals, are held together by the subtle matter flowing around them; or a single particle of water is held together by the subtle circumambient matter;

FIG. B.

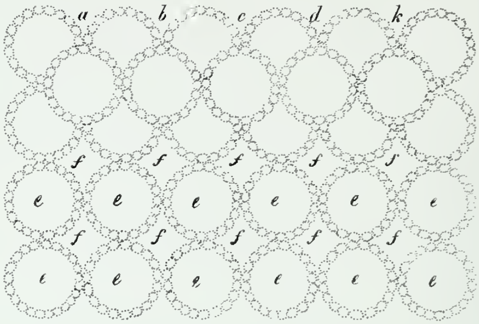


FIG. A.

FIG. D.

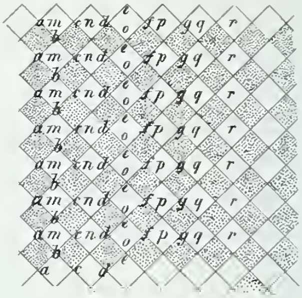


FIG. F.

FIG. C.

FIG. G.

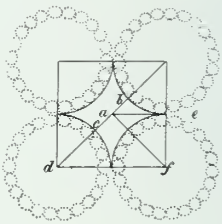


FIG. E

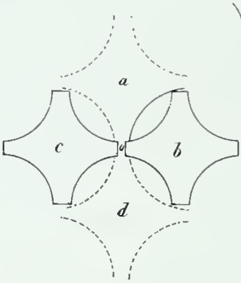


FIG. I.

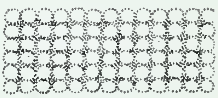
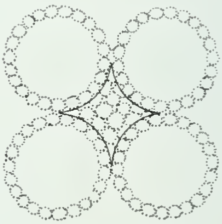


FIG. H.



and so on with the others of the fifth, fourth, and third kinds; for whatever be the element, it possesses the natural property of pressing equally on every side. If the pressure of the subtle matter be equal on all the crustals of the particle of water, they will evidently be kept in their position by the simple pressure around them: for which, consult Parts II. and V. in the *Principles.* 3. But as this subtle matter is deficient in quantity at the bottom of the sea, the particle itself falls into smaller ones; thus, those of the sixth kind into the fifth, fourth, third, &c. 4. If the particles of water be arranged in the fixed quadrilateral pyramidal position, and the aqueous crustals of the fifth and fourth kind be broken up, their interstices must necessarily be filled up, so that the cavities and spaces may be occupied by the particles of water, which have thus been decomposed at the bottom of the sea. 5. That this disintegration, or decomposition gives rise to salts and metals, will be shewn in the following pages.

§ 3. *The shapes of the interstices of water.*

We shall here treat of the shapes of those interstices only, when water remains in the fixed quadrilateral pyramidal position; or, in other words, of the shapes of the spaces between the particles of water at the bottom of the sea; where we think that figures of very different kinds, salts and other substances, are produced. If therefore, the position be the fixed quadrilateral pyramidal, the spaces and interstices between the globules are of two sorts. 1. *The interstices of the first kind are cubes with hollowed sides,* as in Plate III., Fig. A; for if the round particles lie in the position of Fig. B, or fixed quadrilateral pyramidal, *fffff* are the hollowed cubic figures of the interstices. 2. *Other interstices in the same position are cavo-triangular,* possessing four hollowed sides and four points (like Fig. C), to which the cubes are joined, as *abcdk,* Fig. B. 3. *The number of the cubes is equal to that of the particles of water; vide* Fig. B, where in the aforesaid position there are as many spaces *ffff* as there are globules *eeee,* and the same arrangement of particles exists in every layer. 4. *The number of triangles is double that of the particles of water,* vide Fig. D. For the cubes are joined to the triangles, as at *aaaa, bbbb, cccc, dddd, eeee:* where we see that the cubes

are combined in two places, thus, *mmmm*, are joined with the lateral triangles on the left in two places, as at *bbbb, cccc;* thus also the cubes *ooooo*, with the lateral triangles at *eeeee, fffff*, and so forth; so that the number of the triangles is double the number of the particles of water, or double that of the cubes. 5. *Four cubes are united by one triangle*, namely, two lateral and two upper, as at Fig. E, where the triangle at O joins the lateral cubes *ad* and the upper ones *cb*, according to the figure of the interstices of water. This may likewise be proved by the shape itself of the triangle F, where there are four points, to each of which a cube is joined: since therefore, there are eight angles in every cube, it follows that the proportion of two triangles to one cube will be required to connect them together. 6. *The layers of cubes lie alternately in this quadrilateral pyramidal position*, for one cube is not exactly over the other, but over the interstice of the four cubes beneath it; as in Figure E, *ad* are in the lower layer, but *cb* are in the upper, consequently the position of the cubes is alternate in the alternate layers. 7. *The arc of a cube is* 90 *degrees*, or four arcs collectively form a circle, which is shewn by the figure; but the arc of a triangle is only 60 degrees, so that six such arcs are necessary to form a circle, which is also evident in the figure. 8. *The altitude of an interstitial cube*, (as *cb* Fig. G,) *is to the semidiameter of a particle of water as* 4 *to* 5. Let $df=2d$, its square$=4d^2$; the half of which is equal to the square $af^2=2d^2$, whence $da=\frac{7d}{5}$ nearly, and $ca=\frac{7d}{5}-d;=\frac{2d}{5}$ for *ac*, or $\frac{4d}{5}$ for *bc;* that is, *cb* is to *cd* as 4 is to 5.

§ 4. *The weights of the interstitial spaces of water.*

The ratio of the spaces in the fixed quadrilateral pyramidal position has been already demonstrated; viz., the full space (or that which the particles occupy) is to the empty space or interstices, as 3 to 1, as shewn in Part VIII., p. 13. 2. If the empty space or interstices be filled with the hard matter of the fifth kind, which is the crustal matter of the particles of water, as in Plate III., H, we maintain that one cube with

two triangles of that matter will weigh to the particle of water, as 2 to 3. *Demonstration*: let the matter in the particle of water=1. According to the Theory of Water, p. 16, the internal cavity of the particle is half of the space; consequently if it be filled with the same matter, the weight of the particle will =2. Since then, the weights are as the spaces, $3 : 1 :: 2 : \frac{2}{3}$, the weight of the interstitial matter, which compared with the weight of a particle of water, assumed as equal to 1, will be as $\frac{2}{3}$ to 1, or as 2 to 3. Hence it follows, *firstly*, that the cube of such matter, compared with the particle of water, weighs as 1 to 3: because the two triangles occupy half the space, and the cube takes up the other half. *Secondly*, a triangle of the same matter weighs to the particle of water as $\frac{1}{2}$ to 3, or as 1 to 6. 3. If, again, the more subtle hard matter of the fourth kind, insinuate itself into the interstices of this matter, I maintain that the interstitial substance, or one cube with two triangles, will then weigh to the particle of water as 10 to 9. *Demonstration:* Let the aforesaid matter be as 2 to 3; also (but only for the sake of the demonstration) let the internal cavities of these particles, occupying half the space, like the cavity in the particle of water, be filled up; in which case the weight will be double the foregoing, or as 4 to 3. Now, since the ratio of the weights is according to the ratio of the spaces; in the fixed quadrilateral pyramidal position, it will be as $3 : 1 :: 4 : \frac{4}{3}$; to which, if the 2 be added, it becomes $2+\frac{4}{3}=\frac{10}{3}$, and thus, when compared with the weight of the particle of water, taken as 3, it will be, $\frac{10}{3}$ is to 3 as 10 is to 9. Hence it follows, *firstly*, that the cube of such matter weighs to the particle of water, as 5 to 9. *Secondly*, that the triangle of this matter weighs to the particle of water as 5 to 18, because it is half the weight of the cube. 4. If the particles of water be broken up at the bottom of the sea; or in other words, if the crustals of the particles, when in a very quiet state, glide into the interstices of the lower particles, and the spaces, which before were empty, be filled with a new and subtle matter, we hold that new particles and shapes of various kinds are thence generated; and that this is the origin of salts and other matters, which we will demonstrate in our Theory of Salts and Metals. It will then be seen, that the saline matter consists of particles of two kinds, viz., of the fifth and fourth together, as in Plate IV., Fig. A;

and that it is evidently similar to the matter described in section 3 of this paragraph. In this place we have not deduced the weights of the matters beyond the solution or disintegration of the fourth kind: that of the third, second, and other kinds will be mentioned in our Theory of Metals.

FIG. A.

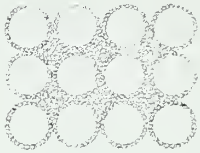


FIG. B

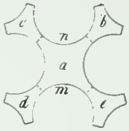


FIG. C

FIG. D

FIG. F.

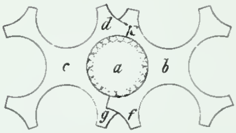


FIG. E.

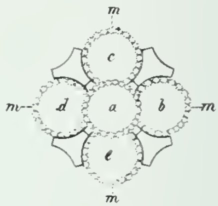
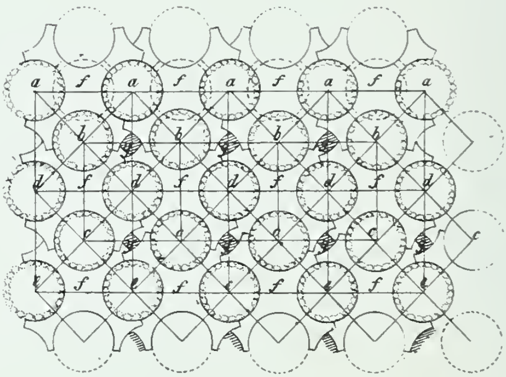


FIG. G.



PART XI.

THE THEORY OF COMMON SALT, CONTAINING GEOMETRICAL AND EXPERIMENTAL DEMONSTRATIONS OF THE INTERNAL MECHANISM OF ITS PARTICLES.

§ 1. *Description of the particles of common salt.*

A PRIORI, OR FROM FIRST PRINCIPLES.

We think that the particle of common salt is generated at the bottom of the sea, by the disintegration or breaking up of the particles of water, and their falling into the interstices below, where the particles of the water are arranged in the fixed quadrilateral pyramidal position; for which, consult Part X., § 1 and 2, p. 28; and Part VIII., § 7, p. 12. We consider, therefore, that the saline particles are produced from the aqueous particles themselves, and are formed in their interstices; consequently, they have a shape like that of the interstices themselves in the fixed quadrilateral pyramidal position. Hence it follows, 1. That *the particles of salt are exactly similar to the figures of the spaces of the water*; because they are shaped according to the interstices of water in the fixed quadrilateral pyramidal position, concerning which see our Treatise on the Shapes of the interstices of Water. 2. *The saline matter is of two kinds, of the fifth and fourth orders of hard particles*; that is to say, it consists of the particles of which the crustals of water and the crusts of those crustals are formed; as shewn in Plate IV., Fig. A, where the larger spheres are the crus-

tals of water, and the smaller ones scattered amongst them are those of the fourth kind. 3. *The shape of the particle of common salt,* according to this theory, *consists of one cube and several triangles;* to be in perfection, it ought to consist of one cube and eight triangles, or of one body or stoma with eight points, as in Plate IV., Fig. B, where *a* is the cube or stoma, and *cbde* are the triangles or points, described in the Treatise on the Shapes of the interstices of Water. 4. *As the number of points or triangles is less, the particle of salt is less perfect.* For if 1, 2, 3, 4, or 6 points be broken off, it will possess so much the less acidity, because there is a smaller number of spicula to produce the acidity; whence the particles of the strongest salt may be considered as possessing many points, and those of the feeblest as having few: varieties being produced in this manner. 5. If no points adhered to the angles of the cube, the remainder or cube *a* would be but a dead substance without taste or acidity; and would form a particle of some kind of earth, as may be seen below. According to this theory, the spicula *bcde* are nothing but the acids, or the acidity of the salt, which being taken away, the remainder is insipid, and a mere stoma. 6. *The height of the particle of common salt by the shortest way from m to n,* (Plate IV., Fig. B,) *is to the semi-diameter of the particle of water as* 4 *to* 5; *vide* the Treatise on the Shapes of the interstices of Water, § 3, section 8. 7. *The arc of the particle of common salt dme,* (Plate IV., Fig. B,) *by the shortest way is* 180 *degrees.* or a semi-circle, according to the aforesaid treatise, § 3. The arc $m=90$, $me=60$, but by the shortest way $=45$, therefore $90+45+45=180$, or a semi-circle. 8. *The particle of common salt with eight triangles weighs to the particle of water as* 25 *to* 9; for which consult the Treatise on the Shapes of the interstices of Water, § 4, section 3: where it will be seen that a cube weighs to a globule of water, as 5 to 9, and a triangle as $2\frac{1}{2}$ to 9; one cube therefore with eight triangles will weigh as 25 to 9. 9. But if the triangles be less in number, the weight of the saline particle is diminished; so that if there be only seven spicula, the saline particle compared to a globule of water will weigh as $22\frac{1}{2}$ to 9; if two be wanting, it will weigh as 20 to 9, and so on. 10. Hence it also follows, that 9 par-

ticles of common salt are produced by the disintegration of 25 particles of water.

A POSTERIORI, OR FROM EXPERIMENTS.

That the truth of natural things may be rendered manifest and lasting, we must consult experience, which ought to be the foundation of our geometrical demonstrations; and it so far agrees with our assertions, as to shew their correctness from beginning to end: thus,

1. The saline element is water, and the particles of common salt are naturally fluid in it. By the solution of salt, the weight of the volume is increased more than the space, so that the saline particles are in the very interstices.

2, 10. The ocean is salt, especially at the equator, but less so towards the poles; hence the bottom of the ocean, and the globules of water, appear to be the receptacle and beginning of salts.

3, 4. There are different kinds of salts, some with their points uninjured, others with them broken off. The flavour of salts is acid, as if produced by angles and points, which the papillæ of the tongue perceive.

5. If the points be broken off by calcination, much boiling, or distillation, the remainder is insipid and without acidity, like the caput mortuum of salt, or alkalised salt.

8, 9. Common salt is heavier than water. But the weight varies according to the acridity, and also according to the kind of salt.

§ 2. *The fluidity of the particles of common salt in water.*

A PRIORI.

If the particles of common salt be generated between the globules of water at the bottom of the sea, and have the shape of their interstices, it follows, 1. That *the concavity of the saline particle is exactly adapted to the convexity of the particles of water;* so that the particle of water is contained and can be moved in the saline cavity, as conveniently as in its own natural place. 2. *The particle of water will move round its axis*

in the saline cavity, and may be driven from it by the slightest touch and motion. For if the saline matter consist of the hard crustals of the fifth and fourth kinds, and the water of those of the sixth and fifth kinds, they cannot be fastened together in any way. Thus in Plate IV., if Fig. C be the particle of water, and D the side of the saline particle, then as the matter of the latter is more subtle, (since it consists of the fourth kind, and consequently is smooth and polished, whilst the crust of the aqueous particle C is rough,) the conjunction between the convexity of the water and the concavity of the salt will be of such a character that it may be broken by the slightest touch. 3. *One saline particle in water is beset by six aqueous particles;* that is to say, when the crystals of common salt are dissolved, every particle is beset by six particles of water, which fit into its cavities, as shewn in Plate IV., Fig. E, where *abcdef* are six particles of water around one of salt. 4. A particle of salt is always attended by these six aqueous particles, whether it move upwards or downwards, and if any one of these aqueous particles be driven from its place, another will immediately succeed it. 5. *Consequently these six particles of water are changed from the natural position into the fixed quadrilateral pyramidal;* but as there is but little difference between these two positions, their fluidity does not vary much. 6. *The saline particle in water does not increase the space, but only occupies the void;* so that whatever quantity of salt there may be in the water, the volume is not in the least increased by the mere particle of salt; but the weight is augmented. Whatever increase of bulk there may be, is derived from the particles of water contained in the mass of salt, as will be mentioned hereafter. Hence the saline particle, according to our theoretical delineation, possesses the following qualities: it can flow easily in water; it fits the convexity of the watery particles; it constitutes one volume with them; it may be separated from them by the slightest touch or motion; it is constantly attended by six aqueous globules, whether it move upwards or downwards, and by this connexion, there is no increase whatever in the volume of the water, but only in the weight.

A POSTERIORI.

1. Water is the menstruum and element of almost all salts,

and especially of common salt, so that the saline particles appear to flow in the spaces between the aqueous globules.

2. Salts may be separated from water in various ways, by fire and heat, and otherwise: water may also be separated from salts, as by distillation; therefore their connexion is not so close as to prevent them from being easily separated from each other.

3, 4, 5. The saltness is diffused throughout the whole mass of water, and divided among the globules; shewing that the salt is surrounded and accompanied everywhere by the aqueous particles.

6. The weight of the volume of water is increased by the salt it holds in solution, since the saline particles occupy the spaces between the particles of water.

§ 3. *Crystallization of common salt.*

A PRIORI.

When, owing to deficiency of water, there are no longer six aqueous particles to surround a saline particle, that combination of the salt and water, called crystallization, begins. From the mechanism of the saline shape, it follows, 1. That *a particle of water may be surrounded and enclosed by two saline particles.* Let the figure of the salt be perfect, consisting of eight points and one cube, then only one particle of water can be intercepted by the cavities of two saline particles. In Plate IV., Fig. F, *a* is an aqueous particle, *b* and *c* are two saline particles, the arcs *ebf* and *dcg* are each 180 degrees, and their arms occupy and inclose a whole particle of water, so that no space is left for a greater number of saline particles; but if the points be broken off, and fewer in number, space is afforded for three or four saline particles around one particle of water, as will be seen hereafter. 2. Therefore the first crystallization takes place when one aqueous particle is surrounded by two of salt; or, when two saline particles are combined together by one aqueous, according to the arrangement in Fig. F: whence crystallization takes place when the water is inclosed by the salt, as fluidity previously existed, when the salt was inclosed by the watery globules. 3. According to the mechanism of the particles, they cannot be arranged together in any other way than that shewn

in Fig. G, where *aaa, bbb, ccc, ddd,* &c., are aqueous particles shut up by the saline particles *fffffff,* over which again fresh aqueous particles rest, at *ffff,* and so on until these lamellæ have concreted together into a mass or crystal. 4. We may here observe, respecting this combination, that *the aqueous particles lie in a right line, as aaaa, bbbb, cccc, dddd,* or as *ade, ade,* and so forth: also obliquely, as *abdce, abdce,* &c. The position therefore of the particles of water in the base of the saline mass, is rectilinear, both parallel to the sides, and obliquely at an angle of 45 degrees. 5. *The particles of salt likewise lie in a right line, and in the same manner as the particles of water,* as *ffffff,* &c. 6. There are small vacancies at the joinings, which are not filled by either salt or water, as at *ggggg;* they also are in a right line. 7. *The saline mass is pellucid,* on account of the rectilinear arrangement of the saline and aqueous particles, and of the empty spaces, but if the arrangement be irregular in any part, it is white like snow: for which consult our Theory of Colours. 8. *The perpendicular plane is exactly the same as the horizontal;* so that if the mass of salt be cut either perpendicularly or horizontally, the section is like Fig. G; whence the mass is cubic, whichever way it is turned. 9. *The mass of common salt is lamellar,* so that one layer can be peeled off and taken away from another, as is evident from the mechanism in Fig. G. 10. *The crystals of common salt are pyramidal cubes, and their planes are cubic;* so that wherever they are broken, a right side will be formed, according to the arrangement in Fig. G. For if any part be broken away, the fracture will take place according to the line of the particles of water, as in *ab,* or *abdce,* or *ce,* or *bdce,* and so on; for the mass is broken at the parts where it is weakest and has the least cohesion; that is to say, at the places of conjunction with the particles of water. And since the aqueous plane ascends perpendicularly, as well as obliquely, at an angle of 45°, the mass is fractured in the direction of the planes shewn in Plate V., Fig. H: the mass being according to Fig. I; because the plane of the particles of water ascends in an oblique direction of 45° towards a point or apex. Hence in a given fracture the crystal also terminates at *m,* which may plainly be perceived in Fig. I. Hence it follows, that wherever the mass is broken, the fracture takes

FIG. H.

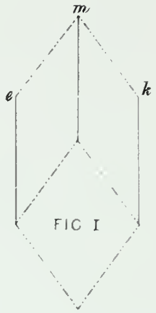


FIG I

FIG. L.

FIG K

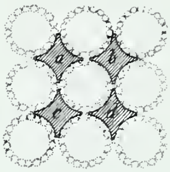


FIG. M

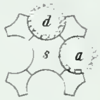
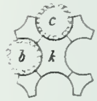


FIG N



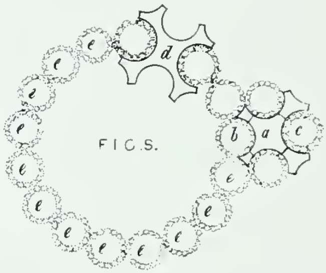


FIG. S.

FIG T

FIG. 2.

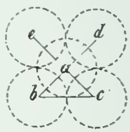
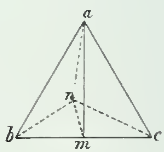


FIG. 1.

FIG. 3



place either cubically, or in a horizontal, perpendicular, or oblique direction, according to its internal mechanism. 11. *The particles of water contained in the mass of salt are arranged in the fixed quadrilateral pyramidal position.* In Fig. G, let *bddc* be a saline cube, in which the particles of water mutually touch each other and form a square. Now if there be any particles above the saline particles *ff*, their arrangement will be the same as in the lower plane, which is in the fixed quadrilateral pyramidal position. 12. *The number of the particles of water in a mass of salt, is to that of the saline particles, as* 3 *to* 1. For to each line of saline particles, as *ffff*, the lines of aqueous particles *eee*, *ccc*, together with as many above, correspond; and so on for every line and stratum; consequently the number of aqueous particles in a mass of salt is three times as great as that of the saline particles. 13. *Other kinds of salt, as the alkaline, cubic and nitrous, can be crystallized with the particles of common salt.* For if any of the points be wanting in a particle of common salt, that particle may nevertheless be combined with the others, although a difference may take place in the regularity of the crystallization; in a word, all those particles which are modelled to the convexity of a particle of water may be joined together in one mass; such are nitrous and vitriolic substances, certain alkalis and acids, common salts, &c. 14. *If the saline particles be not of the same kind, the crystallization is of a confused character.* For if the saline particles be quite perfect, or provided with eight points, then one aqueous globule may be enclosed between two saline particles; but if some of the points be defective, many saline particles may find room round one aqueous globule, and thus a diversity of crystallization and combination will take place, owing to the diversity of the particles; that is, the planes of the mass will be in a state of confusion, from the mingling together of different figures, as I shall elsewhere prove. 15. That *the plane of the crystal of salt inclines at an angle of* 45°, is evident from the following grounds. According to the demonstration above, let the position of the aqueous or saline particles be the fixed quadrilateral pyramidal, since it cannot be any other, owing to their shapes; let five particles be in the abovementioned arrangement, as in Plate V., Fig. 2; let one rest upon the other four, as *a* rests upon *bcde*,

let *abc* be the lines between three centres, and let us pass on to Fig. 3, in which *abc* are the same lines, between three centres; now let a perpendicular fall from the upper centre *a* to the plane of the lower centres, as at *n*, by which the plane *ban* will be formed; in which triangle, in this fixed quadrilateral pyramidal position, the line *an* is equal to the line *bn*, and the angle at *n* is a right angle; if now the lines *na* and *bn* are equal, and include a right angle, the angle *abn* will be of 45°. Whence the crystal of common salt ascends obliquely to an apex by an angle of 45°; for the lines *ab*, *ac*, *ad*, *ae*, Fig. 2, are in an obliquity of 45°. 16. The inclination of the plane itself *bca* is obtained in the following manner; the angle *abn*, Fig. 3, is of 45°, but we wish to ascertain the angle *nma*, which is larger, and is the angle of the plane: let $d =$ the semi-diameter of the globule; therefore in the triangle *abn*, $ab = 2d$, $(an)^2$ or $(bn)^2 = 2d^2$, $bm = d$, also $mn = d$, and the angle *anm* is a right angle; hence $am = \sqrt{(2d^2 + d^2)} = \sqrt{3d^2}$, or $d\sqrt{3}$. The sine of the angle *amn* may be obtained by proportion, thus; as *am* is to *an*, so is the right angle *n* to the sine *m*, or as $\sqrt{3d^2}$ is to $\sqrt{2d^2}$, so is r to $\frac{r\sqrt{2}}{\sqrt{3}}$. Whence, the sine being given, the angle may be obtained from the tables, and is greater than 45°.

But it appears from our Theory of the Origin of Salts, that they are combined at the bottom of the sea in another way; according to Plate V., Figure K, where *abcd* are cubes mutually joined by the aforesaid triangles or points, one cube being combined by two points. In this crystallization, the number of the aqueous particles is equal to that of the saline, and the horizontal plane is similar to the vertical, because the particles are in the fixed quadrilateral pyramidal position; but these subjects will be more fully discussed in the Theory of Stones.

It is evident from their shapes, that *the particles of salt cannot be united to those of water in any other way than that which we have mentioned,* according to the section of the plane, Fig. G, Plate IV. But if the particles are of other forms, the crystallization will be different, which is a necessary consequence and mechanical effect of the two figures

A POSTERIORI.

1, 2, 3. When the water is deficient in quantity, the salts crystallize; for example, when the aqueous globules are driven off by evaporation: hence crystallization is nothing more than a conjunction of water and salts, and it cannot take place, unless the water be previously diminished.

4, 5, 6, 7. The mass or crystal of salt is pellucid; sometimes snow white, which indicates the direct position of the particles.

8, 10, 11. The form of the crystals of salt is cubic.

The crystals of salt are fractured cubically, both perpendicularly and horizontally.

But if they are broken in any other way, no polished plane appears in them.

9. The saline crystals cleave in layers, whichever side is selected.

When a crystal of salt is dissolved, the solution is seen to take place by layers, for the cubic form is preserved throughout it; the salt therefore is dissolved in the weakest parts, which are the aqueous planes.

10, 11, 15, 16. The crystals of common salt are pyramidal cubes.

The crystal of salt terminates in an apex, or small plane.

Its angle appears to be of 45°, so that the position of its particles is the fixed quadrilateral pyramidal.

12. When salt is distilled, phlegm and spirit come over; whence a considerable quantity of water must be contained in the crystal; for which consult § 9.

13. Alkaline, nitrous, and vitriolic salts can likewise be crystallized with the particles of salt.

The crystallization of heterogeneous salts is confused, and not exactly cubic.

Salts of different kinds are found in masses of common salt, as will be shewn hereafter.

§ 4. *The weight of the saline mass.*

A PRIORI.

If the mass of salt be entire, and none of its points be wanting, we maintain that it will weigh to its volume of water as $23\frac{1}{9}$

to 11 : which is thus demonstrated. If the aqueous particles in the mass of salt be arranged in the fixed quadrilateral pyramidal position, according to the calculation mentioned in the Treatise on the different positions of round particles, the weights of the volumes differ, as 12 to 11; that is to say, the volume of water whose particles are in the fixed quadrilateral pyramidal position weighs, when compared with an equal volume of water in the natural position, as 12 to 11. It appears from the Theory of the preceding paragraph, that the aqueous are three times as numerous as the saline particles, and that an entire particle of salt weighs to an aqueous globule as 25 to 9, and to three of these globules as 25 to 27; whence by proportion, as 27 : 25 :: 12 : $11\frac{1}{9}$; to which if we add the weight 12, the sum total will be $23\frac{1}{9}$, the weight of the saline mass, compared to 11, the weight of the water.

But as common salt undergoes the greatest variation by the fracture of its points, for if the particles be much shaken together, some of their points are immediately broken off, so all kinds of salt are not of the same weight, but one is lighter or heavier than another. Nevertheless, it is a general rule; 1. That *in every crystal of common salt, the water contained therein weighs to an equal volume of water as* 12 *to* 11. *Demonstration :* Whether the particles of common salt be whole or mutilated, they cannot be joined with the aqueous particles otherwise than by occupying the interstices or square spaces between them; wherefore the aqueous particles still preserve their fixed quadrilateral pyramidal position, whether the saline particles be entire or not. If the aqueous particles be applied to the hollowed or curved sides of the saline particles, they cannot assume any other position by their connexion with the latter, than that which has been already mentioned. In this case it follows, that in any mass of salt, as many aqueous particles are contained as in a similar volume of water in the fixed quadrilateral pyramidal position, the weight of which, compared to the weight of water, is as 12 to 11. 2. *In every crystal of common salt, the salt contained therein weighs as much as the crystal exceeds the water in weight beyond* 12 *to* 11. For example, let the crystal of salt weigh to its bulk of water as 22 to 11, then we assert that the weight of the salt by itself is 10, and that of the water in it

is 12, for $10+12=22$. Or if the weight of the salt be to that of the water as 18 to 11, then we say that the weight of the salt itself is 6, and that of the water is 12, compared to the volume of water 11. The reason is, the water in the mass is kept in the fixed quadrilateral pyramidal position, and its weight is as 12 to that of water 11; therefore it follows that the excess of weight is due to the salt alone. 3. In order that we may perceive how much the saline masses differ in weight, when some of the points are broken off, we will take the following example. Let there be plain cubes, with the points broken off, naturally crystallized with the particles of water, which cannot occur otherwise than by the aqueous particles occupying the fixed quadrilateral pyramidal position, and the saline particles filling up the square spaces; in this position the number of the saline particles is equal to that of the aqueous globules: and in this case of crystallization, the mass would weigh to the volume of water as $18\frac{2}{3}$ to 11. *Demonstration;* Let the weight of the volume of particles of water in the fixed quadrilateral pyramidal position $=$ 12, to that of water$=11$. Since one cube corresponds to every particle of water, as demonstrated in Part X., § 3, and its weight is to that of the aqueous particle, as 5 to 9, and thus as $6\frac{2}{3}$ to 12: by adding which weight to 12, the weight of this saline mass will be $18\frac{2}{3}$, to 11 of water. But the difference is, *firstly,* that such a mass is destitute of all acidity, and resembles an earth in character, rather than a salt. *Secondly,* it is soluble in the smallest quantity of water, because the water is not at all held in its embrace, as will appear more fully in the next paragraph. *Thirdly,* when the points are broken off, the number of the saline particles is brought up to that of the aqueous globules; for if the saline particles be entire, the number of the aqueous particles is to that of the saline as 3 to 1, but if they have no points, the aqueous and saline particles are equal in number. 4. It appears likewise that another species of crystallization can take place; viz., when all the saline particles mutually cohere by their points; that is, one cube with two triangles, precisely according to the shapes of the interstices of water in the fixed quadrilateral pyramidal position. Now we affirm that *such a mass would weigh to the volume of water, as* $25\frac{1}{3}$ to 11. But it cannot be dissolved, unless by fire, and therefore its properties

will be investigated in the Theory of Stones. 5. Salts vary in weight between $18\frac{2}{3}$ and $23\frac{1}{9}$ to that of water, 11, which follows from what has been said above. Hence it is to be observed, *firstly,* that entire particles of salt may be conjoined and crystallized with those which are not entire. *Secondly,* that whether the saline particles be entire or not, the aqueous particles keep the same fixed quadrilateral pyramidal arrangement. *Thirdly,* that whether the saline particles be entire or not, they crystallize cubically, and also at an angle of 45°. *Fourthly,* that the kinds of salt differ in weight and solubility, but not in shape, &c.

A POSTERIORI.

1. The weight of a mass of the best salt is to the weight of its volume of water as $1\frac{3}{4}$ to 1, which nearly coincides with our calculation.

1, 2. The distillation of salt proves that it contains a considerable quantity of water; *vide* § 9.

3, 4, 5. Salts differ greatly both in goodness and fixity. Thus rock salt is the strongest. Then salt crystallized by the sun. Salt first crystallized, by evaporation, is sharper and better than that which crystallizes the second and third time. In the third and fourth time salt will not crystallize. Boiled salt is not so sharp: and the more it is boiled the less sharp it becomes.

5. Whether the salt be entire or not, or of the best, middling, or worst quality, it nevertheless crystallizes in cubes. Salt which is less entire is soluble in any moisture; and approaches the nature of an alkali: it has not much acidity; it is comparatively light and insipid, and unfit for domestic use.

§ 5. *The solution of salt by water.*

A PRIORI.

From the fixedness and crystallization of salt, a conclusion may be drawn as to its solubility, since the one is reciprocal with the other. Respecting the solubility, we have to observe, 1. That *the more entire a mass of salt, the more fixed it is, and consequently the more difficult to dissolve in water. Demonstration:* If the aqueous particles be embraced by four triangles or

points, they cannot be abstracted unless in a right line, according to Plate IV., Fig. E, where it may be seen that the particle of water cannot get out, except in a right line at *m*; and so on with the others. Or in Fig. G; if the aqueous globules *ade* come forth from their cavities in the salt, it must be in a right line; in the same way, the saline particles *fff* must necessarily be separated from the aqueous particles in a right line; wherefore the mass consisting of entire particles of salt, is comparatively fixed; but this is not the case in a mass in which the angles are defective, for the saline particles can be easily separated from the water, either obliquely, or in any other way. 2. *Owing to the mechanism of its composition, a particle of salt cannot be abstracted from its aqueous particles, except in the direction of its layers or strata: that is, cubically.* In Fig. G, when the watery particles arrive at *a, d,* or *e,* the superficial ones are driven off by any motion which occurs; if the aqueous particles still continue acting, a whole row or layer is separated, which takes place according to the road of the aqueous particles *abd,* or *abdce,* that is, cubically. 3. The separation takes place simply by the motion and elevation of the particles, and in the quietest manner: because the water adheres to the salt by mere contact, and as has been demonstrated in the preceding Parts, it is naturally separable by the least motion which it receives. 4. *The solution of a mass of entire salt in water may go on until the number of the aqueous particles is to that of the saline particles, as* 20 *to* 1. *Demonstration:* If *a,* in Plate V., Fig. L, be a saline particle, *bbbb* the aqueous particles in its cavities, which are six in number, then eight other aqueous particles may adhere to the ends of the points, as at *cccc.* Thus one saline is surrounded by fourteen aqueous particles, and is in this manner prevented from coming into contact with its neighbours. Between these volumes of fourteen particles, other intermediate aqueous particles must necessarily flow; their number is obtained by the ratio of 11 to 5, or as the full space is to the interstitial space in the natural position, which gives us the number 20; so that twenty particles of water are required for one of salt, to prevent mutual friction and contact. 5. Hence it follows, that *a mass of entire salt weighing* 5½ *is soluble in a volume of water weighing* 16; which is thus demonstrated. According to the calculation, there

are twenty particles of water to one of salt; and in the mass 3 of water to 1 of salt, as shewn in § 3 of this Part, sec. 12; whence the weight of the saline mass = 52, since the aqueous particle = 9: three aqueous particles must be subtracted from the volume of water, because they are contained in the mass of salt, and then the remaining 17 will be the weight of the volume. As the weight of a single particle is 9, that of the 17 particles will be 153. On comparing the weights of the salt and of the volume of water, 52 is to 153, as 11 to 32 nearly, or as 5½ to 16. 6. *If the salts, instead of being entire, are mutilated, or deprived of some of their points, less water will be required to dissolve the mass.* For where there is no point, there is neither fixity nor crystallization, unless the water be altogether removed. 7. *When the water in the saline solution is removed by evaporation, common salt cannot crystallize before the number of the particles of water be to those of the salt in a less proportion than* 9 *to* 1. This is demonstrated by the salts crystallizing better in proportion as the number of aqueous particles is less; because, as we have shewn, six aqueous particles can be detained in the saline cavities, and whilst they remain there, one saline particle cannot by any means be connected and joined with another; for N, Plate V., cannot be joined with M, if the cavities be occupied by watery particles. But if there be a less number of aqueous particles, and one part empty, so that the cube *k*, Fig. N, is deprived of the particle *b*, *k* is immediately united with *s*, Fig. M, and crystallization occurs. Let the saline particles, therefore, be encompassed by those of water; and if the latter are in insufficient quantity in the interstices of the volumes of salt, (as actually takes place when the solution is diminished by heat,) the water will necessarily pass from the saline cavities, and when these are evacuated, room is afforded for combination. But if the interstices between the particles of water be full, that is, if besides the above-mentioned number of six, there are yet three others, the particles will not run from the saline cavities, for they are kept in their places; therefore if the number of the aqueous particles, and of the saline, be as 9 to 1, there will be no crystallization; but if they be as 8 to 1, a certain degree of crystallization will ensue; but still more, if the watery particles be only as 5 or 6 to 1 of the saline. 8. *When*

the solution is exposed to the action of fire, the aqueous particles can be dissipated until only 5 *or* 6 *remain for* 1 *particle of salt.* This is demonstrated in the following manner. When the saline particles are in motion, they cannot as yet be united to the aqueous particles; but when they are at rest, this effect takes place immediately, for then the aqueous particles run out from the saline cavities into the vacant intervals, whereby some of the saline surfaces are laid bare, and allow of a conjunction with the aqueous particles. 9. The crystallization of common salt may be submitted to calculation. Thus, in order to know what quantity of common salt can be procured from water evaporated to a certain degree, let it be supposed that no crystallization will take place in water impregnated with salt, unless the number of aqueous particles, in proportion to the saline, be less than 9 to 1. For example, let the ratio be as 7 to 1; and it will follow, according to the theory, that the remainder will be converted into crystals. But we have to ascertain by calculation how much that remainder will be: therefore, if the number of the saline particles in the water $=a$, that of the aqueous particles $=b$, and of the saline particles about to be crystallized $=x$, the number of the particles of water and salt together in the crystallized mass will equal $3x+x$ (*vide* page 39, sect. 12), and $a+b-4x=$ the number of the aqueous and saline particles remaining in the water. According to our theory, the difference is as 1 to 9, which is equal to the lixivial residue, which cannot be crystallized unless the evaporation be carried on afresh: let therefore the difference of the number of the saline particles in the lye since the formation of the crystal $=a-x$, the difference in the aqueous particles $=b-3x$, then these two will be as 1 to 9; or $1 : 9 :: a-x : b-3x = 9a-9x$, or $\frac{9a-b}{6}=x$. For example, let the ratio be as 1 to 7, then a part of this residuum will become crystallized; let $a=1$, and $b=7$: $\frac{9a-b}{6}=\frac{1}{3}=x$. The corresponding number of aqueous particles in this crystal will $=1$, and that of the saline being $\frac{1}{3}$, these are to be deducted from the number of the particles of the volume or lixivial residue, viz., $\frac{1}{3}$ from 1, and 1 from 7; the residual number of the salt will thus be found $=\frac{2}{3}$, and

that of the aqueous particles$=6$; the ratio of $\frac{2}{3}$ to 6 is as 2 to 18, or as 1 to 9, according to our proposition. Hence we obtain the following rules. 10. *The difference of the ratio of the particles of salt and water in a lye from the proportion of $\frac{1}{9}$, divided by 6, is equal to the number of saline particles in the crystals:* which is thus demonstrated. Let the ratio of the evaporated lye be as 1 to 5, the difference $\frac{5}{1}$ and $\frac{9}{1}=4$, which divided by $6=\frac{2}{3}$, which is the number of saline particles in the crystals; and this deducted from 1, leaves $\frac{1}{3}$ as the number of the saline particles remaining in the ley. 11. Or if we wish to obtain the weights, let the salt water be evaporated to such a degree, that the number of the saline particles may be to that of the aqueous particles as 1 to 9, or that it may weigh to common water as 106 to 81. If the weight be still farther increased by evaporation, until the lye weighs to common water as 106 to 68 (or as 70 to 45), or the number of the particles be as 1 to 5, (for nothing but water is driven out by the heat, the salts remaining behind,) only five aqueous particles remain instead of nine: if, according to the rules, the weight of the crystals be required, it may be obtained by the above-mentioned calculation. The number of the saline particles in the crystals$=\frac{2}{3}$, and that of the aqueous$=2$, or together $=2\frac{2}{3}$, the weight of which is$=2+\frac{50}{27}=3\frac{23}{27}$, $=$the weight of the crystals. The weight of the former lye, in which the numbers of the saline and aqueous particles are as 1 to 9, is $11\frac{7}{9}$; but when it has been evaporated to such a degree that the particles are as 1 to 5, its weight is equal to $7\frac{7}{9}$; and that of the lixivial residuum$=7\frac{7}{9}-3\frac{23}{27}$, or$=3\frac{25}{27}$. Hence we see, *firstly,* that salt water, when the numbers of the saline and aqueous particles are as 1 to 9, weighs to the volume of pure water as 106 to 81, or as $11\frac{7}{9}$ to 9: *secondly,* that when the evaporation has proceeded so far that the salt water weighs $7\frac{7}{9}$, the weight of that part which can be crystallized is $3\frac{23}{27}$: *thirdly,* that the residuum of the lye weighs $3\frac{25}{27}$.

We have likewise to observe on the solution of salt, 1. That *the saline particles slightly change the position of the aqueous particles,* for since the saline particles enclose the aqueous ones in their cavities, and reduce them to the fixed quadrilateral pyramidal position, therefore all those particles which adhere in

any way to the hollow sides of the saline particles, are transposed from the natural into the pyramidal position, the others retaining their former arrangement. 2. When the saline mass is dissolved, the subtle igneous matter flowing between the aqueous globules, is expelled from its situation, into which the saline particles succeed, and drive it upwards. *Therefore in a saline solution, the subtle matter rises to the surface in the form of bubbles, and its place is occupied by the salts.* 3. Hence it follows, that *salt water is not only more tranquil than fresh,* (as being deprived of the subtle matter which flowed through it,) *but also colder;* on which subject see our Treatise on Cold. 4. Since each saline particle is surrounded by at least six aqueous ones, it is not surprizing that *it may be filtered through blotting paper,* &c., because there is no point in any part to prevent its passage.

A POSTERIORI.

1, 6. Salt too much boiled is not so fixed as salt which has been less boiled. Salt of the first crystallization is more fixed than that of the second or third. Rock salt, and salt crystallized by the heat of the sun, are the most fixed. Salt can be fixed by acid liquids. In proportion as the triangular points are lost, salt becomes more soluble; because when the points are broken off, the aqueous particles are no longer so closely embraced within the cavities of the saline particle.

2. Whilst a crystal of salt is dissolving or diminishing in water, it still preserves the cubic form; which is a sign that the layers are taken off or raised by the watery particles according to the aqueous planes.

In the same way, when portions are removed, the cleavage is generally cubical and in layers; when this is not the case, the broken side appears rough.

3. The solution in water goes on quietly, and only seems to be an elevation of the particles or planes.

4. A crystal of salt weighing 11 may be dissolved in a volume of water weighing 32; or about 11 loths* of salt in a pound of

* The *loth* is nearly equal to half an ounce English.

common water; which exactly coincides with the calculated proportion of $5\frac{1}{2}$ to 16, or 11 to 32.

7, 8, 9. When a saline solution is evaporated to a certain degree, crystallization commences. In some salts this is indicated by a pellicle forming on the surface of the evaporated liquor.

10, 11. When a part of the salt is crystallized, and the residue again submitted to the fire, and brought to a certain degree of density, crystals will again be deposited; to obtain which, the liquor ought to be put in a quiet place, or in a cellar. But the precise degree required, has not been well ascertained; generally two thirds of the water are driven off by the fire, which likewise coincides with our calculation; for salt may be dissolved in water until the number of aqueous particles is to that of the saline as 20 to 1, though it cannot crystallize before the ratio is as 9 to 1. Hence if two thirds be taken away, the remainder will be nearly as 6 to 1; whence a part must be crystallized.

12. When a mass of salt is dissolved, the water froths without heat, and bubbles of the subtle matter are thrown up to the surface, something like globules also adheres to the sides. These are signs that the empty spaces between the aqueous particles are occupied, and that the subtle matter therein contained is driven upwards.

Salt water is colder than fresh. Hence common water may be converted into ice by certain salts; for example, by snow water and a solution of salt.

Salt water remains more tranquil than fresh water.

Salt water is clearer than fresh.

A solution of common salt may be filtered through blotting paper.

§ 6. *The weight of a solution of salt.*

A PRIORI.

We have now to take into consideration the increase of the solution in bulk and weight. For it is well known that salt water is heavier than fresh, so that the degree of saltness may be determined by the weight; and this fact likewise indicates,

that the saline particles do not require any separate place for themselves, but that they are contained in the interstices between the particles of water. With respect to the volume or bulk, it follows from our principles, 1. That *a volume of fresh water is increased by the solution of a saline mass to about the same bulk which the mass of salt itself occupies:* that is to say, the bulk of the water is increased when the mass of salt is dissolved in it, by as much space as the mass itself occupies in the water. *Demonstration:* When the particles of water contained in the salt are added to the particles of the fresh water, the number of the latter is increased by the number of those in the salt, that is, they increase the bulk by their own bulk; but it is not so with the saline particles, which only occupy the space in the interstices, according to the demonstrations in the preceding theories. For we know that in the mass of salt the aqueous particles are in the fixed quadrilateral pyramidal position, which is a somewhat closer arrangement than that of the particles of fluid water. Therefore, since the aqueous particles are released from their bonds, and added to the number of the others, the bulk must necessarily be increased; and as, when enclosed in the mass of salt, they are in the fixed quadrilateral pyramidal position, but when released from it, in the natural position, the difference of their spaces and volumes will be as 11 to 12; and consequently there must be an increase of bulk by the accession of the fresh particles of water quite equal to the bulk of the saline mass itself.

2. As to the weight, it follows that by the solution of the salt the weight of the volume is increased; but in what proportion will be seen presently. We have shewn that the mere particles of salt cannot at all add to the bulk, but only to the weight, because they occupy the spaces between the aqueous particles. The proportion in which the weight is increased, may be obtained by the following rule:—*The weight of salt water is to the weight of crystallized salt contained in it, as the weight of the volume of salt water multiplied by the ratio $\frac{25}{27}$, is to the difference of the weights of salt water and of fresh:* which is thus demonstrated. Let the weight of the volume of fresh water $= b$; the weight of the volume of salt water $= d$, the difference $= d - b$; this difference is equal to the weight of the particles of salt

contained in the water. Now before they can crystallize and become a solid mass, three particles of water are required for one of salt; or an increase of weight from 25 to 27; hence $d-b$ is increased to $\frac{27\,(d-b)}{25}$ for the weight of the saline mass; if this be compared with the weight of salt water, it will be as $\frac{27\,(d-b)}{25}$ to d, or as $d-b$ to $\frac{25d}{27}$, according to our rule. Now let the weight of the volume of salt water$=35$, and that of the same volume of fresh water$=32$; then the difference $=3$, and d multiplied by $\frac{25}{27}=\frac{875}{27}$, or$=32\frac{11}{27}$, which compared with 3, is as 11 to 1 nearly; and so on with the rest. 3. But if we wish to know the increase of weight acquired by the solution of salt from the water contained in a given mass of salt, it is thus obtained according to our rule. Let the bulk of the volume of fresh water$=c$, the bulk of the saline mass$=d$, the weight of the volume of fresh water$=a$, that of the mass of salt $=b$. Now if the salt be dissolved in the water, we say that *the increased weight of the volume is to the weight of the volume of fresh water as* $1+\frac{25cb}{52a\times(d+c)}$ *to* 1; which is thus demonstrated. The bulk of the volume of water$=c$, that of the saline mass $=d$, together they afford a compound bulk $=d+c$, so that the volume of the water after the mixture or solution$=d+c$. Now, *cæteris paribus*, the weights of water are in proportion to the volumes. Hence, to obtain the weight of the volume of pure water, let $c : d+c :: a : \frac{ad+ac}{c}$ = the weight of the volume of the water in the solution; but the augmentation of weight takes place simply by the accession of the particles of salt, which is in the mass as $52 : 25 :: b : \frac{25b}{52}$, for the weight alone of the particles of salt. Add this weight to the volume of water $\frac{ad+ac}{c}$ which then becomes $\frac{ad+ac}{c}+\frac{25b}{52}$ = the weight of the volume of salt water, which when compared with the weight of the volume of fresh water, is as $\frac{ad+ac}{c}+\frac{25b}{52}$ to $\frac{ad+ac}{c}$,

or as $\frac{52ad+52ac+25cb}{52c}$ to $\frac{ad+ac}{c}$; which in smaller terms is as $1+\frac{25cb}{52a\times(d+c)}$ to 1.

A POSTERIORI.

1. When a crystal of salt is dissolved, the water is increased in bulk, by nearly as much as the space the mass itself occupies in the water; for the aqueous particles are liberated from the mass, and added to the volume of the water.

2, 3. Water impregnated with salt is heavier than common water, because saline particles occupy its interstices.

A volume of water is heavy in proportion as it contains salt; so that the quantity of salt contained may be ascertained from the weight of the solution.

More salt is contained in water than equals the difference of weight between salt water and fresh; because in crystallized salt more than half the weight is owing to the water in it.

§ 7. *The evaporation of a solution of salt.*

A PRIORI.

The particles of common salt do not follow those of water into the air, or pass with them into vapour, but remain in the lye, as is evident from our Theory of the evaporation of salt water. In the treatise on the Evaporation of Water, we have shewn that vapours are nothing more than small aqueous bullæ, and that evaporation is only the transformation of the particles of water into bullæ, of which they occupy the surface; the interiors being filled with a matter lighter than air, viz., the igneous, by which they are brought to an equilibrium with the air, and mount up spontaneously: but these topics are more fully mentioned in the treatise itself. Hence it is to be observed, —1. That *the particle of common salt cannot subsist with the aqueous particles in the surface of the vapour.* In Plate V., let S be a particle of vapour, *eeeee* the aqueous particles on its surface; a saline particle cannot be held between them without

causing the total destruction of the bulla. For if the saline particle be in the place *a*, it would not only be beyond the surface of the bulla, but it would likewise be accompanied by some of the aqueous particles, and would be weighed down towards *ab;* and thus having a downward tendency, it would break the vapour particle by destroying its rotundity. In the same way, if the salt occupied the place *d*, the bulla would perish in losing its equilibrium. Since therefore the water escapes into the air in vapours and bullæ, (as is demonstrated in the Theory of Fire,) and since the saline particles are not adapted to their formation, therefore all the salts remain behind, whilst the water flies away. Hence, 2. If the water be evaporated by the heat of the sun, the salt remains, whilst the water rises into the air. 3. In the same way, if salt water or a saline lye be submitted to fire, the aqueous portion alone departs, but the saline remains. 4. Or if the water flow off, either in pure air or through heaps of twigs, or if it be thrown upwards, the saline part falls towards the bottom, but the aqueous flies away. 5. The same result happens when a saline mass is subjected to distillation; no entire particles of salt leave the retort, but only fragments, owing to the reason already mentioned, of the unfitness of the salt to enter into the bullular form assumed by the water which escapes in vapour.

A POSTERIORI.

1. Water containing salt may be evaporated by the heat of the sun; when the salt remains and forms crystals. The same result is also obtained by fire and boiling.

If water containing salt be thrown out, and dispersed in the air, the saline particles remain, whilst the aqueous fly away. This is evident at the sea coast, where the water strikes against the rocks, and casts foam on high; and where the water in holes and cavities of the rocks is found to be pure, and hardly at all salt.

In the same way, if salt water falls into the free air through small pipes and heaps of twigs, it becomes heavier and more loaded with salt; because a part of the pure water flies off into

the atmosphere; this takes place best when the air is serene, with a very slight wind.

When a solution of common salt is contained in a glass vessel, the water may be observed creeping upwards on the sides of the glass, and carrying the saline particles with it, which crystallize there in tolerable thickness, when the water flies away. We may thus perceive that the particles of common salt cannot in any way accompany the water into the air; that is to say, they cannot subsist in the watery vapours, but slip down again by their own weight.

In the same way, the salt does not issue from the retort with the water, and impregnate the spirit of salt, unless it first be broken; but whatever of salt is found in the said spirit of salt, is formed subsequently by a certain conjunction of the particles, treated of in § 9, and in our Theory of Acid.

§ 8. *The fracture of the particles of common salt.*

A PRIORI.

Three observations occur to us concerning the fracture of large particles into smaller. *Firstly.* In proportion as the particle is smaller, it is better adapted to the central motion; so that the smaller particles may be driven round with a very rapid central motion, but the larger ones are more calculated for local motion. This property may be observed not only in salts, but in elementary particles also, for they are quick in axillary gyration in proportion as they are subtle. *Secondly.* Particles of an unequal shape break in those parts where they are weakest, that is, where they are slenderest, according to the natural mechanism of fracture; for whatever breaks, breaks at the weakest part. Salts are in this case, for when set in axillary motion, their sharp points are easily broken off by the shock from other particles, especially if the central motion be rapid. This takes place just as with bodies on a large scale, which, if they are moved round an axis, approach nearer and nearer to the spherical form, because the weaker prominences and inequalities are broken off. *Thirdly.* The smaller particles are set in violent motion by fire. As to the solution of the saline particles, we may con-

clude from their shape, that when they move on their axes, their prominences or points are broken off, and fractured in their weakest parts; whence we have observed, 1. That *the particles of common salt are broken and divided into smaller particles by the least central motion, because they have angular parts;* and according to the preceding rules, they are broken in those parts where they are the weakest, that is, the triangles are broken off from their cubes at the thinnest spot between the two; *vide* Plate V., Fig. T, which shews that the particle of salt is thinnest at the joinings *bcde,* where also it is broken by any central motion, or friction with other particles. 2. *The remainder is a stoma,* or that square body described in § 1 of this Part, section 3; *and the fractured parts are the concave triangles bg, cg, dg, eg,* described in the same paragraph. 3. *All the triangular parts or points may be torn away from one particle of common salt;* that is to say, *eight triangles from one cube.* 4. The theory of the fracture follows from the very shape of the saline particle, and its conjunction with the aqueous particles. For example, in distillation, where the motion of the particles is tremulous and central; the particle U or W, (Plate VI.,) moves centrally with its six aqueous particles; the rest likewise move in the same way. If volumes of such particles move about their axis, it is not at all extraordinary that the prominences *cccc* or *aaaa* should be broken by shocks from other prominences; and if the motion of the distilling fire be continued, the particle of common salt in the volume of six aqueous particles may be so broken, as to assume the shape of Fig. W, in which the angular parts *aaaa* are torn off from the square body at the parts *nnnn.* 5. *No central gyration of the particles of common salt can take place without water;* because the bare particles everywhere meet with others, and are mutually entangled in their arms and embraces; but this does not occur when they are furnished with aqueous particles. 6. *When the particles of common salt are submitted to distillation, no entire saline particle can possibly escape in an unbroken state: vide* § 7, section 1. 7. In the same way, if the aqueous portion be driven off by evaporation, until the number of aqueous particles to the saline is as 6 to 1, and the solution be divided and granulated into volumes of this kind,

FIG U.

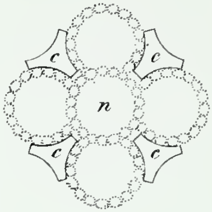


FIG W.

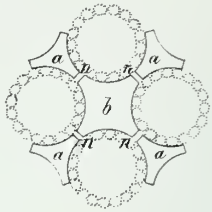


FIG X

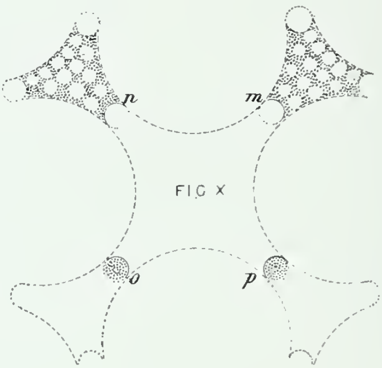


FIG. Y

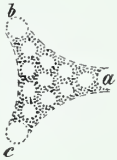


FIG. Z.

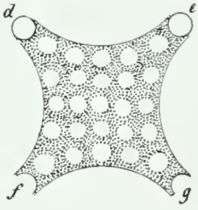
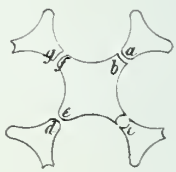


FIG. 2.



then we maintain that if the central motion be continued, the particles will be broken. Whence, 8, *if salt be frequently dissolved and crystallized by fire, it becomes gradually weaker, loses its acidity, and therewith its fixity and aptitude for conjunction;* so that if it be crystallized three or four times, at length it will no longer bind together, owing to the loss of its arms, as has already been shewn. 9. In the same way, if saline masses be exposed to the action of fire, and be calcined, the angular parts are necessarily broken, (which is evinced by a certain crepitation); though in an entirely different manner, viz., by the disruption of the mass according to the cleavage of the aqueous plane. 10. We may, from these considerations, observe the difference between broken saline particles, and those which are entire; for in proportion as the angles or points are broken off, less acidity and saltness remain; whence there may be salts, which are not more than half salts, having only three or four whole points instead of eight; and which are not only less crystallizable, but are not so fit for domestic purposes, and are very easily dissolved by any kind of moisture.

We here also maintain, that the fracture of the saline particles takes place according to the mechanism of their internal structure; that is to say, the plane of the fracture, or the broken part itself, is round, and partly hollow. Let X (Plate VI.) be a particle of common salt, whose internal construction, as shewn in X, Y, or Z, consists of hard particles of the fifth and fourth kinds. When they are of the fifth kind, they are very similar to those of water, although of but one tenth the diameter; hence when the particle X is broken at *m, n, o, p,* one of the fractured parts possesses the convexity of a globule of the fifth kind, but the other has a concavity; as in Fig. Y, where the parts *b* and *c* are round, but *a* is hollow; or in Fig. Z, where there is a convexity at *e* and *d,* but a concavity at *f* and *g,* which is a result of the composition of the interiors of the particles. But it is very difficult to determine in what parts the hollows and rotundities occur; we think that they happen fortuitously and alternately.

A POSTERIORI.

1. When the salt water of the sea is in motion, it scatters a kind of faint fire or light, which is a sign that the saline particles are broken by the motion. In fresh water this appearance does not occur.

If a mass of common salt be broken in the dark, a feeble light is visible, indicating the fracture of the particles.

When common salt is calcined, it crepitates and gives out a sound, which likewise proves some fracture of the particles; for if it be then distilled, more phlegm than acid is obtained; the taste itself also betrays that the particles are broken, for it is insipid.

When common salt is liquefied by fire, it is converted into alkali, becomes insipid, and loses above an eighth part of its weight.

Rock salt is the sharpest and strongest, because it has not yet undergone either fracture or motion.

Next comes salt crystallized by the sun, which has been but little moved about or agitated. Then boiled salt; and the less it is boiled, the sharper it is, and *vice versâ:* so that the salt is found to be broken in proportion as it is agitated, and the contrary.

If the solution be subjected for a long time to an evaporating heat, the salt will be much weakened; for salt crystallizes best the first time, because it is then most entire: the second time not so easily, nor so abundantly, because it is somewhat broken: the third or fourth time it will no longer crystallize, because the points are broken off, by which the particles of the salt were joined to those of the water.

This fact is also proved by the effervescence of salt with other substances; for salt crystallized the first time, effervesces with the fixed alkalies, as with the oil of tartar per deliquium: but salt of the second crystallization unites with the oil of tartar, and forms a thick precipitate: hence we may perceive a difference between whole and broken salt.

When a solution of salt, or salt water, is much heated for a length of time, an insipid caput mortuum, resembling an earth, is found in the corners of the vessel; and which the

workmen usually remove through pipes placed in the middle. It indicates that the salt is broken by the motion of the fire and aqueous particles, and by the shocks it meets with among the latter.

The lye of salt, which will no longer crystallize, has an acid taste, caused by the points and broken saline parts.

When common salt is distilled, much acid comes over from the retort; that is, much of the matter which has been torn off from the saline body; for which, *vide* § 9. This result is produced by the motion of the saline particles in the retort, caused by the distilling fire.

After the distillation, an insipid earth or caput mortuum remains; shewing that the angles and sharp parts have been torn away.

When common salt is either crystallized or distilled by heat, a substance of a sulphurous and urinous nature is found in the covers of the vessels, or in the necks of the retorts, which indicates that parts have been torn away from the saline body.

The crystals of common salt may be dissolved by acid spirits, but with some noise and fracture of the particles.

In some parts both of England and Egypt, the land is manured with common salt; for which purpose it is broken small; the larger crystals of salt being unfit for vegetation, as will be shewn elsewhere.

Hence it may be seen that the saline particles are broken and divided into smaller ones by motion and the action of fire, and that the fracture takes place at the weakest parts, or at the joinings of the points with the cubes.

§ 9. *The distillation of common salt.*

A PRIORI.

That the following subjects may be more clearly understood, we will here describe what we mean by *point* [*acumen*], *cube*, &c. We call a particle of common salt *entire*, when it consists of one cube and eight triangles, according to the description at p. 33. By a cube, we mean an alkaline particle of any kind: by

a triangle or point, an acid; on this subject there are many remarks in the Theory of Alkalies and Acids. We will now proceed to Distillation, concerning which we have to observe,

1. That *a distilling fire not only causes the particles to move centrally, but the aqueous particles to escape in vapours.* 2. *The particle of common salt cannot accompany the small bullæ of water or vapours on their passage from the retort,* owing to the loss of equilibrium and rupture of surface in the bullæ, as has already been shewn. 3. *When six aqueous particles are contained in the arms of one saline particle, and this volume gyrates centrally, the two cannot be separated, that is, the water cannot recede from the saline body in motion, unless a fracture of the points takes place.* Let U, Plate VI., represent a volume of the particles of water and salt together; we maintain that unless the points *cccc* are broken away, the aqueous particles cannot be separated from them, nor come to the same level with the other watery globules. But when the triangles are torn away, as in Plate VIII., Fig. 20, or in W, Plate VI., as *aaaa* in the weakest parts *nnnn,* the aqueous particles are no longer shut up in the arms, nor hindered by the embraces of the saline particle, but the triangles are separated from the cube by the aqueous particles, and they depart together into the watery surface of the vapour. Let Fig. 1, Plate V., be a particle of vapour or bulla, which has become light by being filled with the subtle matter, and is about to leave the retort; if the saline volume A adhere to its surface, the aqueous particles included in its arms cannot be separated, or depart with the others to the same surface, in any other way than by the separation and fracture of the arms *aaaa.* When thus set at liberty, they separate spontaneously from the volume, and proceed to the surface of the vapour with the aqueous particles: that is, the points *aaaa* lodge in the interstices of the surface of the water, as at *b, c, d,* &c.; and so on all around. 4. *These triangles or points are very well adapted to take up their position in the interstices of the superficial particles of water;* for as, according to our theory, the triangles are very regular figures modelled to the interstices of four globules of water, they find a most convenient place between the superficial aqueous particles of the bulla; and no loss of equilibrium need be feared, for the

surface may be filled with them equally on every side. 5. *If we examine the position of the particles of water on the surface of the bulla, we find that it is the triangular:* and the number of the aqueous particles in that position will be to the number of the interstices as 1 to 2; that is, there will be two interstices for every aqueous particle, and consequently, there will be two places for the acids to one particle of water; so that no larger number of points can follow the bulla of vapour than can be dissolved and arranged round its surface. If a small saline volume contain six aqueous particles and eight triangles, the eight triangles or acid particles will accompany the six aqueous particles into the surface of the bulla. 6. *When the interstices of the vapour are full of triangles, a red colour is seen; but when the vapours are of different sizes, a white colour is exhibited;* as will be mentioned in our Theory of Red and White.

Now the above-mentioned triangles or broken points are acids. 1. If the mass of salt be distilled with bole, clay, sand, lime, or other similar matter, *a phlegm will pass over, which should weigh to the mass of salt as* 9 *to* 52, or as $2\frac{1}{4}$ to 13. *Demonstration:* We think that the phlegm is nothing more than the superficial water of the salt, which flies away before the mass is completely loosened; for the surface of the saline mass must necessarily be surrounded by many aqueous particles, since there are such a number of cavities calculated to receive them: and also since the salt is broken according to the planes of the aqueous particles. Hence there are cavities filled with aqueous particles, which are driven off at once on the application of fire; for as they are not detained by any arms or embraces, they easily pass into vapour, and escape from the retort. *Secondly.* In proportion as the saline masses are smaller in size, or pounded into smaller grains, their surface is larger, and consequently their superficial water is more abundant; as is evident from geometry. As the particle is small, so the surface is large in proportion to its body; so that the finer the powder into which the salt is reduced, the more superficial water is there. And since salts are pulverized for distillation, we may conjecture that a third part of the water contained in the mass without any fracture passes over; but there will be less when the

saline masses are larger. Let us therefore assume the third part, according to this opinion. Now since there are three aqueous particles in the mass to one saline, the weight of an aqueous particle$=9$, the weight of a saline particle$=25$; and the total weight of the saline and aqueous particles$=25+27=52$: hence if a third part of the water flies away without any acid, it follows that this portion will weigh to the saline mass as 9 to 52, or as $2\frac{1}{4}$ to 13; which is the phlegm. 2. *An acid spirit of salt then comes over; and should weigh to the mass of salt, as* $24\frac{2}{3}$ *to* 52: which is thus demonstrated. As one of the three particles of water has already passed away as phlegm, there are two remaining, the weight of which to that of the mass of salt is as 18 to 52. Since the acids accompany the aqueous particles, and since according to the theory of this paragraph, the number of the acid particles is to the aqueous as 8 to 6, we obtain $2\frac{2}{3}$ for the number of the acid particles to the two aqueous particles; the weight of $2\frac{2}{3}$ acid particles is to one aqueous as $6\frac{2}{3}$ to 9; if this be added to 18, the weight of the water and acids together, or of the acid spirit$=24\frac{2}{3}$, to the mass of salt, 52. 3. *The phlegm and acid spirit together weigh to the mass of salt as* $33\frac{2}{3}$ *to* 52, or nearly as $7\frac{2}{3}$ to 12; which follows from the preceding calculations. Here, however, we must observe that a larger or smaller quantity is obtained according to the various methods of distillation; but the greatest proportion of the matter which comes over in distilling, to that which remains behind, is as 33 to 52. But less acid and more phlegm are obtained if the triangles have previously been torn asunder by calcination; there is also more phlegm if the salts be reduced to fine powder, &c. 4. *The residue of the salt, or the mass of the caput mortuum, weighs to the whole mass as* $18\frac{1}{3}$ *to* 52; which likewise follows from the same calculations. 5. *After this first distillation some triangles still remain, which have not yet been torn away from their cubes;* since according to the theory no greater number of acid particles can be broken away than the quantity of water permits. For unless six aqueous particles embrace one particle of common salt, they cannot by any means be broken, but are bound together till a fresh supply of water arrives. Agreeably, therefore, to the demonstration, let the number of the acid particles, which have gone over, be as $2\frac{2}{3}$ to 8. 6. *Hence there*

will still remain some acid particles destitute of aqueous particles, the number of which, to the whole number of acid particles, is as $5\frac{1}{3}$ *to* 8; for when $2\frac{2}{3}$ have departed, $5\frac{1}{3}$ remain. 7. *If an additional quantity of water be absorbed from the atmosphere, the remainder may again be distilled into spirit;* and this, not once only, but seven, eight, or nine times, until there is no longer any acid remaining. The reason why we say, from the atmosphere, is, because aërial water insinuates itself better and with more appropriate number of particles into the vacant spaces, or saline cavities, than if it was poured on them; for if the quantity be greater than the empty cavities require, the chief part flies away in phlegm; since one particle of acid can pass over with eight or nine aqueous ones, which would form mere phlegm or vinegar: but if the number of the aqueous particles corresponds to the number of the cavities in the salt, then the ratio of the water and acid is as 6 to 8, which constitutes the acid spirit. 8. If the common salt be very pure, *an acid spirit may be procured from one mass by several distillations, weighing to the saline mass as* 74 *to* 52: which is thus demonstrated. Let the number of aqueous particles be to the number of acid particles in the spirit of salt, according to our theory, as 6 to 8; if the water be insufficient the first time, let it be replenished a second, third, and fourth time, until all the acid has been converted into spirit; the weight of the 6 particles of water $=54$; the weight of the 8 acid particles $=20$, and together they weigh 74, to the weight of the saline mass 52. More spirit, therefore, may be obtained than the saline mass itself weighs, if the distillation be properly conducted. 9. *After the distillation has been completed, the caput mortuum weighs to the mass of salt as* 5 *to* 52; that is to say, when there is no more acid remaining, this is the weight of the cubes as compared with the mass of salt.

A POSTERIORI.

1. In the preceding paragraph we have shewn that the particles are agitated and broken by the distilling fire, and in other ways.

2. When common salt is distilled, it is resolved into phlegm or water, and acid, which together constitute a sort of acid spirit called spirit of salt.

In distillation, the salt does not come forth in a whole condition, but it is broken, or divided into water and acid.

4. When the acid spirit comes forth, it is at first of a snow-white colour, and then red; which is a sign that the acid and aqueous particles are mixed together on the surface of the vapour, and that light is transmitted through them in various ways: for which consult our Theory of Light and Colours.

5. The same result takes place if an acid spirit be distilled from nitre and other salts; indicating that acids occupy the spaces between the particles of water on the surface of the vapour. But in the spirit itself, there is a certain limpidity and watery appearance.

6. When salt is distilled with bole, clay, or other substance,—for example, one part of salt with six of bole,—a sort of phlegm first of all comes over, then an acid, or acid spirit; and an insipid substance remains behind at the bottom of the retort.

The phlegm that comes over is snow white, but the acid is red; this however is still more evident when nitre is distilled.

A great heat is necessary for distilling common salt, viz., to break off the points occupied by the aqueous particles.

If the salt be previously calcined or decrepitated, it affords in distillation more phlegm than acid, because some of the points are broken off, and the salt is surrounded by many aqueous particles.

3. Experience shews that when a mass of common salt is distilled for the first time, phlegm and spirit come over, which together weigh to the whole mass of salt as 7 to 12: this coincides with our calculation, which gives us $7\frac{2}{3}$ to 12. The weight may differ in different distillations, in proportion to the method adopted for distilling, pulverizing, and mixing the saline mass with the bole. If the bole be scanty in quantity, or the fire very fierce, one particle of salt may be joined to another, the aqueous particles may be shut up among entire particles of salt, and many other results may take place; for which consult our Theory of Alkalies.

7. Common salt may be distilled repeatedly; in one case it

was treated as often as nine times, and some spirit was always obtained.

Before each fresh distillation, the caput mortuum is exposed to the air, from which it gathers new strength, or absorbs fresh aqueous particles.

8. More acid spirit may be distilled from a saline mass than is equivalent to the weight of the mass itself, provided the caput mortuum be frequently exposed to the air; the increase of weight being due to the accession of fresh aqueous particles.

§ 10. *The combination of fractured salts.*

A PRIORI.

It appears from the internal structure of the particles of salt, that broken salts may again unite and combine into particles of common salt; as we have fully shewn in our treatise on lixivial Alkalis. In this place we shall merely observe, 1. *That the broken particles of salt may be re-united by means of water, although not otherwise.* For the saline figures are like those of the interstices of water; and hence they move and work in the latter, and by means of water may be brought into mutual contact, and applied to each other; so that the extremity of one shall meet the extremity of another, and consequently one unite with another, convexity fitting into concavity, and *vice versâ.* In fact, when the extremities are joined, they will necessarily cohere, and reässume the shape that they previously had. 2. If then the saline particles be broken, so that one extremity is convex, and the other concave, they may be joined together again by means of water: see Plate VI., Fig. 2. If the concave part *b* is applied to the convex part *a*, they will unite by geometrical necessity, and the ball will enter into the socket; the two being conjoined (when the external subtle matter is shut out) just like any two polished bodies. 3. But this will not take place, if the hollow part *c* is applied to the hollow part *b*, or the globose *d* to the globose *e*. Therefore broken saline particles may be recombined by means of water, in the interstices of which they move; but this cannot take place out of water; as will be seen more clearly in our Theory of Acids and Alkalis.

A POSTERIORI.

It has been ascertained by a great variety of experiments, that broken salts will recombine. Thus alkaline particles not only effervesce with acids, but also combine with them. And this takes place, not merely by the joining of angles, but likewise by the division of the alkalis by the acids into saline particles. But the nature of alkalis must be known before an idea can be formed of their conjunction with acids; and therefore we defer for the present our statement of the experiments on this subject, which will be of considerable length.

P.S. In opposition to the theory that common salt originates in water, it may be objected that salts are not only found in the ocean and other waters, but also on land; for there are whole mountains of salt; there are salts in herbs and vegetables, in the soil, and even in the stones themselves, whence they may be extracted by calcination. This seems to militate against my theory of the origin of salts at the bottom of the ocean and between the particles of water; but I shall obviate this objection by shewing, in a treatise on the Depth of the Primeval Ocean, and that, too, by numerous and convincing proofs, that a primeval sea once stood at an immense height above the surface of our present land; that in the lapse of time it subsided to the level of our land and ocean; and that the soil on which we now dwell was formerly the bottom of a sea, in which mountains of salt and stone, as well as all saline compounds, originated.

FIG. 1.

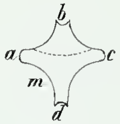


FIG. 2.

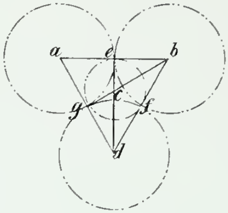


FIG. 3.

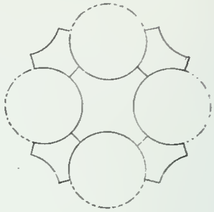


FIG. 4.

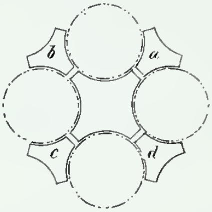


FIG. 5.

FIG. 6.

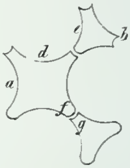


FIG. 7.

FIG. 10.

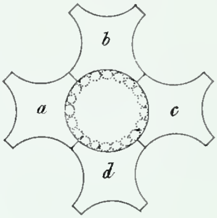


FIG. 9.

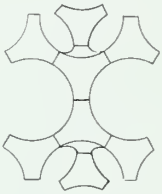


FIG. 8.

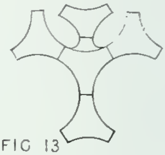


FIG. 13

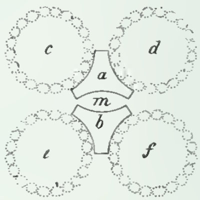


FIG. 11.

FIG. 12.

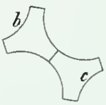


FIG. 14.

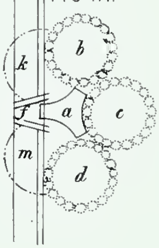


FIG. 15.

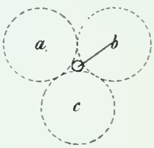
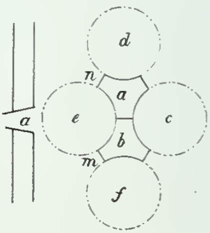


FIG. 16.



PART XII.

THE THEORY OF ACID, CONTAINING GEOMETRICAL AND EXPERIMENTAL DEMONSTRATIONS OF THE PARTICLE OF THE ACID OF SALT; AND SHEWING THE MECHANISM OF ITS FIGURE.

§ 1. *Description of the particles of the acid of salt.*

A PRIORI.

HAVING ascertained the dimensions of the particle of common salt and of its acuminated portions, we also know the dimensions of the particles of the acid of salt. For our view is, that the acid is nothing more than the points of the common salt; in other words, that the acidity or sharpness of the salt constitutes the acid. In knowing the origin of common salt, we have a key to the knowledge of the figure, size, arcs and weight of its particles. According to the description in the preceding pages, and in our treatise on the Shape of the Interstices of Water, § 3, it follows, 1. That *the particle of the acid of salt is a very regular triangle, excavated equally on all sides in conformity to the dimensions of the particle of water;* that is to say, it is a solid triangle of very regular form, which has originated between four aqueous particles, and corresponds in shape to their interstices; as in Plate VII., Fig. 1, where the sides *dc, da, ab* and *bc,* are hollowed out to fit the arc of the aqueous particle. 2. *A particle of acid has four hollow sides and four extremities or pointed portions,* as *a, b, c, d.* 3. *The acids are tòrn away*

from the particle of common salt. Eight of these acids or acid particles are attached to its angular extremities; and when they are broken off, the saline particle loses its acidity, which gradually passes over and forms the acid; what is left being a caput mortuum, without either taste, fixity, or saline properties. 4. *The arc of an acid particle is* 60°, although the corresponding straight line is only 45°. Thus in Plate VII., Fig. 1, *cd* is an arc of 60°, but the straight line from *c* to *m* is only 45°; as we know from the fact that the acid originates between four aqueous particles. In Fig. 2, the arc *ef*, or *eg*, =60°. 5. *The semidiameter of an acid particle is to the semidiameter of an aqueous particle as* 4 *to* 7. Let *ce (Ibid.*, Fig. 2) = the semidiameter of the acid, and *eb*=the semidiameter of the aqueous particle; then by the squares we have the side $ed=\frac{7d}{4}$; or $ad^2-ae^2=de^2$, or $3d^2$, the root of which is $\frac{7d}{4}$ nearly. From these data the side *ec* may be obtained by proportion: thus, in two similar triangles, $ed : ea :: eb : ec$, or $\frac{7d}{4} : d :: d : \frac{4d}{7}$, which compared with the semidiameter *d* of the aqueous particle is as 4 to 7. 6. *The height of one acid particle* (that is to say, by a straight line from *m* to *c*, Fig. 1) *is to the semidiameter of an aqueous particle as* 9 *to* 14; which is demonstrated as follows. From the similarity between the triangles *edb* and *ecb*, the base *cb* may be obtained by proportion. Thus $ed : bd :: eb : cb$; or $\frac{7d}{4} : 2d :: d : \frac{8d}{7} = cb$. If another particle of water be placed upon the three conjoined particles *abd*; and if the centre of the particle *b* be joined to the centre of this new particle, this will be done by a straight line$=2d$. Now let the base$=bc$; and the altitude from the plane *c* to the centre of the upper particle may be obtained by the squares of the sides, for the squares of the altitude$=4d^2-\frac{64d^2}{49}=\frac{132d^2}{49}$. Hence the altitude$=\frac{23d}{14}$ nearly; from which the semidiameter *d* must be deducted; and the remainder is the height of the acid particle *mc*, Fig. 1, which equals $\frac{9d}{14}$, and this altitude compared with the semidiameter of

the aqueous particle is as 9 to 14. 7. *The weight of a particle of the acid of salt* (according to our treatise on the Interstitial Shapes of Water, § 4), *is to the weight of an aqueous particle as* 5 *to* 18, or to a particle of common salt as 1 to 10.

From Part XI., § 8, where we treated of the Fracture of Common Salt, we know that some of the broken ends are concave, but others convex, that is to say, when the acid is snapped off from the salt, some of the fractured extremities are balls, while others are like sockets; as in Plate VII., Fig. 1, where *b* and *d* are concave, and *a* and *c* are convex. This is owing to the internal matter of the salt, which consists of hard globules of the fifth and fourths kinds; and every time it is broken, the fracture necessarily follows the convexity or surface of some one globule. And so, as chance directs, the acid particles have in some instances concave extremities, in others, convex.

A POSTERIORI.

1. An acid, usually termed the spirit of salt, is obtained by the distillation of common salt. This acid appears therefore to originate from the latter, and to consist of its acuminated portions and extremities, separated by the fire applied for the distillation.

It will be seen in the sequel that an acid spirit is also procured from other salts.

It is especially noteworthy, that the acid mixes with the water, without impairing its fluidity; which shews that the acid particles may exist among those of the water; *i.e.* in the spaces between them.

The acid spirit is heavier than water, which indicates the same.

The true figure and weight of the acid particles may be ascertained by measurement of the crystals and liquors.

§ 2. *The distillation of the acid liquor.*

A PRIORI.

It is to be observed on this subject, 1. *That when the crystals* or granules *of common salt are distilled, the saline particles en-*

closed in the volume formed by the six aqueous ones are set in strong motion; as in Plate VII., Fig. 3, where one particle of salt is impacted among six of water, and forming a volume with the latter, moves, in company with many others, round its axis and centre, until the angular portions, Fig. 4, *abcd,* are broken, and wrenched from the stoma or body; whereby the particles of salt are disintegrated, and reduced to smaller parts, and in this condition issue from the retort. 2. *It follows from this, that when common salt is distilled, six particles of water come over in company with eight of acid.* 3. *The particles of water are always so disposed on the surface of vapoury bullæ, that the number of the interstices is to that of the particles as* 2 *to* 1*;* for they are in the triangular position; and therefore the acid particles will occupy twelve, or at least eight, of the interstices between the six particles of water. 4. From these data we may obtain the weight of the acid liquor. For as there are six water and eight acid particles, and as the weight of a particle of water $=18$, and that of a particle of acid$=5$, so $3:4::1:\frac{4}{3}$, which is the number of the acid particles. If the weight of a water particle$=18$, and of an acid particle$=5$, then the weight of $\frac{4}{3}$ of an acid particle$=6\frac{2}{3}$, so that the weight of the acid contained in the spirit$=6\frac{2}{3}$, and of the water$=18$, and together they weigh $24\frac{2}{3}$, which is the weight of the acid liquor: so that if pure water weigh 18, an equal volume of this liquid acid will weigh $24\frac{2}{3}$.

A POSTERIORI.

1. When common salt is distilled with bole, phlegm* first comes over, then an acid liquor termed spirit of salt: which shews that the acid particles are portions broken from common salt.

Salt may be distilled many times, in fact, according to experience, as many as nine, and still yield fresh acid. When distilled the first time, the weight of the phlegm and spirit together is to that of the whole mass as 7 to 12: which propor-

* "PHLEGM [among *Chemists*] water, one of the five chemical principles; also a waterish distilled liquor, opposite to a spirituous liquor." *Bailey's Dictionary.—Tr.*

tion corresponds almost exactly with the number of the acid and water particles that come over.

2. When the acid comes over, a red colour is produced; which is a sign that the particles of acid are mixed with particles of water; also that the two are susceptible of being united in one and the same surface, without the disruption of the bulla of vapour.

4. The acid spirit is heavier than plain water; a sign that the acid particles do not require any fresh space in the water; but occupy the interstices between the particles of the latter.

§ 3. *The conjunction of acids, and the different kinds of the same.*

A PRIORI.

If we examine the intimate construction of an acid particle, we shall find, according to the description already given, that its extremities are partly concave, and partly convex. By the laws of mechanics, therefore, 1. *When acid particles are moving about in water, one may be conjoined with another,* and the convexity of one may be applied to the concavity of another. Thus in Plate VII., Fig. 5, if the acid particle *d* be applied to *a*, or the convex part *c* to the concave *b*, then agreeably to the mechanics of the case, the two may unite; *c* being applied to *b*, and *vice versâ;* and combine to form one body. This takes place most readily in water, since the acid particles float above and move in its interstices, and meeting in all directions join one with another, whereby greater and lesser compounds consisting of acids are produced. 2. *Hence acids are not of one kind alone, but of several kinds; the first, simplest, or smallest of which* would appear to resemble Figs. 1, 5, or 6, already described. The *second* kind is shewn in Fig. 7, and is no more than a reduplication of the acid particles. The *third* kind is represented in Fig. 8, in which five acid particles combine to form one body. The *fourth* is, when eight particles so combine, according to Fig. 9. 3. It is clear from the internal constitution of the particles, that the fracture by which they are detached from the stoma of the particle of common salt, occurs

where the latter is weakest, and that one of the broken ends is concave, the other convex. And as the breadth of the extremity is equal to only $\frac{1}{7}$ of the diameter of one water particle, and as the diameter of the globule is of the fifth kind, so the difference is not too great to allow the fracture from following the dimension or surface of a single globe of the fifth kind; that is to say, in the thinner parts.

A POSTERIORI.

1. Experience proves that acids of various kinds exist; thus we have the acid spirit of salt; the acid spirit of nitre; the acid spirit of vitriol and sulphur; the acid spirit of sal ammoniac, of urine, and of the different kinds of wine; the metallic and mercurial acid; the acid spirit of common and distilled vinegar, and of new and old wine; aqua fortis, or the mixture of spirit of nitre and spirit of vitriol; aqua regia, made by mixing a fourth part of common salt, or of sal ammoniac, with one part of spirit of nitre.

2. One kind of acid liquid differs greatly from another in its power as a menstruum, thus,

3. Spirit of salt will not dissolve metals in the same degree as aqua fortis, &c.; neither will spirit of nitre, nor that of vitriol, unless they are mixed.

Spirit of salt is compatible with spirit of wine, but other acids are not. It yields a peculiar crystalline salt by evaporation.

4. Spirits of nitre and of vitriol effervesce when mixed; and the result is aqua fortis.

It appears then that acids are most diverse in their kinds, according to their different combinations.

§ 4. *The combination of acids with other salts.*

A PRIORI.

It may be shewn that acids combine not only with acids, but with alkalis also: but in this place we shall touch but slightly on this subject, as we have considered it at some length in our Theory of Alkalis. 1. *If an acid particle meet with one of salt*

that is dismembered of any of its points; for example, with a particle of common salt from which an acid particle has been broken, and if the new acid particle be applied to the broken part, and the end of the one be convex, and that of the other concave, in this case *the two will necessarily combine;* as we have stated in our Theory of Acids. Or if a saline stoma or cube that has been denuded of its points, meets in water with acid particles, and convexity is presented to concavity, then, through means of the water, a junction will take place, and a single particle be produced: as in Fig. 6, where the cube *a* meets the acid *b* at *d* and *e*, and at *f* and *g*. Thus if eight particles of the kind beset a saline cube, we again have a particle of common salt presented. Just in the same way in fact that the particles are dissolved or decomposed by motion, they may be reassociated by the intervention of water. 2. *This conjunction may take place to such an extent as to produce not only a particle of common salt, but even a larger particle.* Thus two or three cubes may be joined together by two or three acid particles, precisely as at the bottom of the sea, where the globules lie in the fixed quadrilateral pyramidal position. See Fig. 10, where the cubes *a* and *c* are joined by the acid particles *b* and *d*, and form a single hard body. And the same may take place both above and below; but on this subject we refer the reader to our Theory of Alkalis.

A POSTERIORI.

1. If salt be repeatedly evaporated and crystallized, it is combined with oil of tartar, and forms a dense precipitate.

The salt of the last crystallization is insoluble in water, but soluble in vinegar.

When an acid is mixed with alkalis, the mixture effervesces and froths up, and in some cases heat is produced; but after the effervescence, the mixture is still and the combination of the different particles takes place. When the effervescence ceases, common salt is often reproduced; as when spirit of nitre, spirit of salt, or any other acid spirit, is poured into an alkaline solution. *Vide* Alkalis.

These data will enable us to comprehend the effervescence

that takes place when salts are combining. Thus when an acid particle combines by means of water with a trunk or stoma of salt, and the ball of the one fits into the socket of the other, *this must necessarily occur with reference to the shape of the interstices of water* : for if otherwise, the new compound will again be broken. Thus if the particle represented in Plate VII., Fig. 10, be joined to the particle represented in Fig. 11, the shape of the resulting compound will clearly be at variance with that of the interstices between the water particles; and for this reason, as well as because the shape is ill adapted to follow the motion of the water particles, it will break either at *a*, *b*, or *c*. The same result takes place if the particle of Fig. 12 meets and combines with those of Figs. 11 or 10. Now these various processes of combination and disruption occurring among the particles, will necessarily give rise to a tremulous motion, and the latter to froth and heat, and other species of reaction. To say nothing of *the disintegration or decomposition of the larger alkalis, consisting of a number of great cubes and salts, and which is caused by acids, through the agency of fiery, oily, and urinous particles, &c.* But of this we speak in our Theory of Alkalis.

§ 5. *The weight of acid spirits.*

A PRIORI.

Acid spirit is nothing more than water with particles of acid interspersed, and this is the reason why it is heavier than common water. In fact, 1. *The acid particle exactly fits the triangular interstices between the water particles, four of which will naturally enclose it.* 2. But there is nothing in the acid to delay or detain the water particle, for it has no arms like common salt; and therefore *the water particles will never be fixed by those of the acid of salt, but will be separated from the latter by the slightest motion,* and change their places, to be immediately succeeded by other particles of the same kind. 3. When water is in the fluid state, *i.e.* when its particles are in the natural position, there are only two triangular spaces to each of its particles; in which case, *the acidity of the liquid is necessarily limited to the proportion of two particles of acid to one*

particle of water. 4. If the proportion of acid particles be greater than this, *the water will no longer retain its fluidity, but will thicken and form a corrosive substance.* 5. *If pure water weigh* 18, *and if there be one particle of acid to one of water, the weight of the compound fluid will be to that of common water as* 23 *to* 18. 6. *If there be two particles of acid to one of water, the weight of the acid spirit to that of common water will be as* 14 *to* 9. 7. *Therefore the maximum weight of the liquid acid is to that of water as* 14 *to* 9. 8. *The difference of weight between the volume of water and that of the liquid acid is equivalent to the weight of the acid particles.* Let the weight of the volume of water $= a$, and the weight of the volume of acid $= b$; if they are of the same volume, but different in weight, the difference will be $b - a =$ the weight of the acid of salt. For example, let the ratio of the weights of the particles of water and of acid be as 18 to 5, and let the difference $b - a = 2$, more or less; then the weight of the acid in the spirit or vinegar will be to that of the water as 2 to 18. If we wish to obtain the number of the acid particles, we may obtain it thus. If 5×18 give one particle of acid, what will 2×18 give: according to which $90 : 1 :: 36 : \frac{18}{45}$; whence the proportion between the particles of water and acid is as 45 to 18, or 5 water to 2 acid. With respect to the fluidity of the acid particles in the water, they seem to dwell exclusively in the triangular interstices, and to change their place with the water particles. Thus in Plate VII., Fig. 13, if the water particles *cdef* be in the natural or square position, then the acid particles will lie between them, as in *a* and *b*. And as the square space *m* is full of subtle matter, they cannot possibly be thrust inwards without the subtle matter being previously driven off. Hence when the particles of water are set in motion, the acid particles move in all directions, and keep their places in the triangular interstices of the water.

A POSTERIORI.

The specific gravity of acid spirit has not yet been correctly ascertained. The following points however are generally known:

1. Acid spirit is much heavier than common water; and also than a [saturated ?] solution of common salt.

One spirit is heavier than another.

The weight is increased when the water is driven off by evaporation, whether the latter be caused by fire, or whether it consist in insensible exhalation.

The acid spirit may be reduced to a dense substance, that is even more acrid and corrosive than the liquid.

These facts shew, that the weight of the acid spirit or menstruum is increased in proportion as its particles are multiplied; and that in point of weight and acidity it may be raised from the strength of vinegar up to that of the most corrosive spirit: which agrees with our theoretical assertion.

§ 6. *The force of the menstruum of acids in water.*

A PRIORI.

We have already stated that the particle of acid does not move in water in the same manner as that of common salt; that is to say, it is not accompanied in its course by a number of water particles. In fact, the acid has no hooks or arms to clasp the water particle, and therefore the latter recedes from the side of the former whenever any impulse takes it; and so the one is separated from the other by the slightest cause. But on this subject we have spoken in our Theory of Salt. From this circumstance, namely, that the water may be separated from the acid without any difficulty, inasmuch as the acid particles dwell merely in the triangular interstices of the water, it follows, 1. *That if the acid particle meets with any hard substance having pores into which its extremities can enter, its point will be driven into the pore by the particles of water.* In Plate VII., Fig. 14, let *a* be the acid, and *b, c, d,* the aqueous particles; now if they meet with the hard body *km* having a pore *f* adapted to the point of the acid, we maintain that in that case, *firstly,* the three lateral particles of water, viz., *b, d,* and the water particle at *a,* are easily separated from the acid particle, by any trifling force; owing to the facility with which water particles are separated from saline, as already mentioned, and the still greater facility with which they are separated from acid particles, inasmuch as the latter have no arms. *Secondly.*

When the separation is effected, *the acid particle is impelled in no direction but from behind; i.e. from c, or in a right line, to the point or apex f, by the water particle c.* The lateral particles *bad* are removed; therefore the water particle *c* drives the acid particle *a* in a right line towards *f*. *Thirdly.* Water particles, as well as all elemental particles, press equally in every direction, both upwards, downwards, and sidewards, with a force proportioned to the height of their column, and this therefore is the case with the particle *c*; and thus *the pressure of the acid particle towards the pore or orifice is according to the depth of the water, or in proportion to the height of its column. Fourthly. The pressure of the water is according to the pressure of the atmosphere and the height of its column; and the intrusive force of the acid menstruum is likewise according to the same; whence, if the pressure of the column of water be diminished, the force of the menstruum also is diminished. Fifthly. The acid particle forms an excavated regular triangle, and is wedge-shaped, and on this account may be driven into the pores with the same ease and power that a wedge is driven mechanically into a cleft;* so that the menstrual power of acids depends as much upon the fluidity subsisting among the water particles, as upon the wedge-like shape of the acid itself. *Sixthly. The mechanism upon which decomposition or disintegration depends is multiplied by the multiplication of the wedges;* for if there be a multitude of wedges, the mechanical power is multiplied in proportion; the acid triangles likewise exercise a multiplied power on the substances with which they come in contact.

We have said that acids are of various kinds, large and small; the simplest of which consist of mere points and triangles. Now it is to be observed, 1. That *an acid particle of the latter description will act as a menstruum upon the smallest and the most compact bodies;* such as iron, silver, and the other metals. 2. *It will enter a pore, whose diameter is to that of a particle of water as* 1 *to* 7, *or even less.* This is demonstrated as follows. Let *a, b, c,* Plate VII., Fig. 15, be water particles, with an acid particle of the first kind in their interstices; the diameter of the enclosed pore *o* will be one-seventh the greater diameter; so that the point of this acid particle cannot be larger than one-seventh the diameter of the water particle by which it is pushed

into the substances that it meets with. Moreover as its extremity is concave, or convex, that is to say, terminated by a globule of the 5th kind, whose diameter is one-tenth that of a water particle, so it may be driven into a pore whose diameter is also one-tenth that of the same; and hence it is capable of being insinuated into the metals, and into the minutest places. Although if we examine the origin of the acid particle, we shall find that the diameter of its acuminated surface is larger, according to Plate XI., Fig. 2, where the acuminated portion is comparatively broad, and is thin on three of its sides; yet we suppose that these fine-pointed parts are destroyed in the fractures, as at *bc*, *if* and *nl*, and form fragmentary pieces; leaving the trunk of that shapc we have so often delineated. But on this subject see our Theory of Urinous Substances. From what has been stated we conclude, that the diameter of the extremity of this minutest acid particle is betwcen a seventh and a tenth of that of a particle of water.

2. The second kind of acid particle is composed of two of the smaller particles, according to Plate VII., Fig. 16. Respecting this we have to observe, 1. That this particle is nearer in its properties to lixivial salt, than to acid. 2. If its broad part *e* comes opposite to the pore *a*, its length prevents it from entering the latter directly; and therefore it has but little power as a menstruum, except in a pore into which the water particles that precede it can also enter. With respect to the dimensions of this acid particle, it appears, 3. That the arc or curve of the smaller side *d* is 60°, but in a straight line 45°, and its diameter is to that of the water particle as 4 to 7. 4. The arc of the larger side *mn* is 120°, but in a straight line 90°; and the diameter of this side is to that of the water particle as 5 to 7. 8. Its weight is double that of the acid particle, or as 5 to 9, compared with the weight of a particle of water.

3. The third kind is a composition of five acid particles, as in Plate VIII., Fig. 17, which represents the acid with its water particles, or as in Fig. 8, where the five acid particles are visible. It is a concave and very regular solid triangle, with four hollowed sides and four points. Respecting this kind of acid it is to be observed, 1. That its extremity may be pushed in by water particles almost in the same way as that of the acid

FIG. 17.

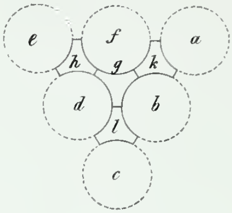


FIG. 18.

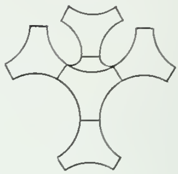


FIG. 19.

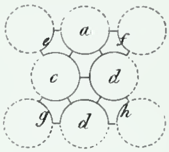


FIG. 20.

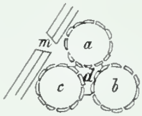


FIG. 21.

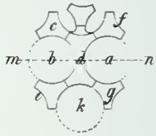


FIG. 22.

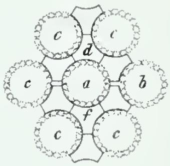


FIG. 23.

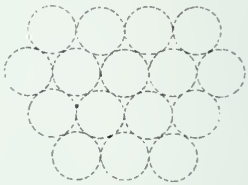
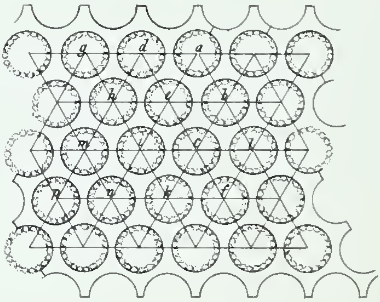


FIG. 24



of the first kind, viz., in a right line from *b*, Fig. 20. 2. The lateral particles of water, *dbg*, &c., are not so easily dislodged from this acid as from the acid of the first kind, because they are inclosed as it were in its arms: hence it follows, 3. That this acid will exert its force upon those metals that have comparative large or loose pores. With respect to its dimensions, 4. The diameter of each of its points is to that of a particle of water as 4 to 7: the diameter of its embrace, or *ec*, is to the diameter of a water particle as 9 to 7. 5. Its weight is to that of a particle of water as $12\frac{1}{2}$ to 9. We believe, for good reasons, that one part of the spirit of salt consists of particles of this order.

4. The fourth kind is formed, when eight acid particles combine, as in Plate VII., Fig. 9, and Plate VIII., Fig. 19 and 21. There is nothing peculiar to be observed respecting it, except that it is not adapted to act as a menstruum; it seems to possess qualities like those of common salt, so far as concerns the minute orifices, papillæ, and nervous fibrils of the tongue.

5. The menstrual power of common salt is not however slight, although it is only exerted on the papillæ of the tongue, and the looser and larger pores that are like them, where it is manifested by a peculiar sense. And it is to be observed, that when any part of it strikes upon a surface, or comes in contact with a pore, penetration is prevented by the water inclosed in its arms, as by *a*, Fig. 19. Nevertheless its menstrual power is manifest in this respect, that it is propelled by the water particles directly into the pore, and its four points at once are pushed into the same spot.

A POSTERIORI.

1. An acid has a peculiar menstrual power, by which it acts upon hard bodies, and resolves them into small and invisible parts: such is the case with spirit of nitre, spirit or oil of vitriol, spirits of sulphur, of common salt, of sal ammoniac, of distilled vinegar, and with some essential salts; also with compounds, as aqua fortis, aqua regia, &c.

All metals are soluble in acids, so also are certain kinds of

salts, and certain calcareous stones. Also various species of wood and other lighter substances.

Particles dissolved by the action of acid menstrua, are no longer visible in water, and moreover they float about in it, until they are precipitated. It is therefore evident, that there is something in acid particles that impels them, that enters into the pores, that divides parts from each other, and that has mechanical properties like a wedge; also that the acids are helped on to the division of substances by the water particles.

2. The power of menstrua differs in different situations. Likewise at different altitudes; it is greater in low situations than in high: on lofty mountains, it is frequently little, and frequently not displayed at all.

It is feeble, or wanting, in an exhausted receiver.

These phenomena exactly coincide with our mechanical view of the particles of water and acid. If the acid particles are wedge-shaped, and the wedges are driven by the water particles, this will certainly take place by help of the atmosphere, and in proportion to the height of its column. As soon as three water particles have receded from the sides of an acid particle, and only one drives it forward from behind, the acid particle will be left as it were in vacuo, where the water particle can exert no power from behind, unless it be assisted by the pressure of a column of air; agreeably to the ascertained laws of physics, and to the assertion in our theory.

3. The menstrual power in acids differs also according to the quality and quantity of the acid particles.

Metals that are dissolved by one kind of acid, are not dissolved by another. Thus the spirit of nitre dissolves many upon which the spirit of salt does not act. Aqua fortis dissolves many that are not soluble in other spirits. Aqua regia acts upon those that aqua fortis does not touch. Vinegar acts where even stronger acid spirits are inert.

One acid spirit dissolves better and more quickly than another, and less of one is requisite than of another.

One kind of acid dissolves metals quietly. A second kind, with heat, effervescence, noise and froth. A third kind, with change of colour; respecting which see our Theory of Metals.

These facts are sufficient to shew that there are acids of

different kinds, or acid compounds of various proportions: some large, some small, others mixed; and that the menstrual power is exerted with a corresponding difference according to the fitness subsisting between the points and the pores.

The larger salts also, as, for instance, common salt, have some solvent or menstrual power, but only on papillæ, as those of the tongue: and which power is felt as pungency.

§ 7. *The loss of the powers of the menstruum when it is deprived of water.*

A PRIORI.

Water is the main adjunct that gives menstrual power to angular and pointed particles; for the water holds the acid particles in its interstices, and carries them along with it against any substances it encounters; and it easily separates from the acids whenever they fall upon a pore. Hence it follows, 1. *That acid particles have no menstrual power apart from or out of water, but are at once deprived of their vehicle as well as of their impulsive force.* 2. *If instead of water, there be a particle in whose surface the acid sticks, as, for instance, a particle of oil, in this case likewise the power of the menstruum is destroyed.* Thus in Plate VIII., Fig. 20, the surface of the oil particles *a, b, c,* consists of a comparatively subtle matter, and is easily applied to any saline surface whatever.

A POSTERIORI.

1. The menstrual power of acid is destroyed by oil; likewise by spirit of wine.

It is frequently coagulated by oily and fatty substances.

Much acid is contained in sulphur, and in various species of bitumen and fat, but it is inert, and without action upon other substances. It is evident, then, that water is a kind of vehicle for pushing the acid particles into the bodies with which they come in contact: as we have asserted to be the case.

§ 8. *The appearance presented by acids after crystallization.*

A PRIORI.

The particles of common salt are provided with hooks and arms, in consequence of which they enjoy collectively a kind of fixity; but this is not the case with the first order of acids, inasmuch as they are destitute of these means of embrace. Hence, 1. *If the acid spirit be evaporated, it cannot crystallize, but will form a thick mass.* 2. *As many acid particles will be contained in the mass as there are interstices.* 3. *The particles of water in the mass will be transferred from the natural position into the fixed triangular pyramidal;* that is to say, into a position in which the interstitial spaces are simply triangles. 4. *In this mass, the number of the acid particles is to that of the water particles as* 4 *to* 1. In this position, in fact, there are four interstices for each particle of water. 5. *Therefore the weight of such mass is to the weight of the corresponding volume of water as* 38 *to* 17. *Demonstration:* The space of the natural position is to that of the fixed triangular pyramidal as 18 to 17, and the weights of their respective volumes are as 17 to 18 reciprocally. Hence when the particles are in the latter position, the weight is greater in the same volume. Now there are four interstices for each water particle, and consequently four acids. But if the weight of the water particle be 18, that of the acid will be 5: therefore that of four acids will be to that of one water as 10 to 9. The increased weight may be obtained by proportion: thus, $9 : 10 :: 18 : 20$; whence $18+20=38=$ the weight of that mass, which is to the corresponding volume of water as 38 to 17. But this weight will be less when the acid particles are fewer in number, and some of the interstitial spaces are not filled with them. 6. *The planes of the acid crystallization cannot be regular or exactly formed;* for the crystals are but little fixed, being soluble by any kind of moisture.

With respect to the crystallization of the fourth kind (page 79), it may be observed, 1. That it may take place just in the same manner as that of common salt, because it has angular arms and embracements, wherein the particles of water

are enclosed, and from which they cannot escape, except in a line perpendicular to the centre of the particle. In Plate VIII., Fig. 21, *abk* are water particles; the rest is a particle of acid of the fourth order. Now we affirm that the water particles are enclosed by it in the same way as by common salt; for the arc *fdg* measures in the longest line 240°, and 180 in the shortest. Hence if a particle of water be enclosed therein, it can escape only in a direction perpendicular to the centre of the particle; for unless *a* recedes from *m* in a right line, the water particle will be enclosed just as it is by common salt. 2. If two particles of this kind be joined together by one water particle, they will crystallize in the same manner as common salt. 3. These particles will unite into crystals at angles of 60 and 120°, according to the figure of the regular parallelogram; but the particles of common salt crystallize at right angles. 4. These particles constitute a hexagonal base: see Figs. 22, 23, where *d* and *f* are acid saline particles of this description, and *abccccc* are water particles. Now if the two saline particles be combined by one water particle; that is, if *d* and *f* be united by *a*; they will constitute a hexagon.* It is further to be observed of these crystals, 5, that the water particles they contain are in the fixed triangular pyramidal position (page 11), while on the other hand, in a mass of common salt the waters are in the fixed quadrilateral pyramidal position (page 12). 6. The plane of the particles of water is according to the plane of the particles in the fixed triangular pyramidal position, as in Fig. 24. 7. The water particles lie parallel to each other in right lines, following the sides of a regular hexagon; as in Fig. 24, *gda, heb, mic*; or *ab, dec, ghi*; or *dh, aei, bck*, &c. 8. The crystals are of an exceedingly regular form; in some the base is hexagonal; in others pentagonal. 9. The six sides are perpendicular, two and two being respectively parallel, as in hexagonal cubes. 10. The mass is divisible in the direction and line of its water particles; as at *dhm*, or *abl*. 11. It is divisible into layers; and this, both horizontally and obliquely at an angle of 60°. 12. It is dissolved by water in the same manner as common salt. 13. The number of the water particles in the crystals to that of the

* Fig. 22 only represents the adjoining halves of the respective acid particles.—*Tr.*

saline particles is as 2 to 1; but in the mass of common salt the proportion is as 3 to 1. 14. The weight of the mass is to the weight of the corresponding volume of water as 38 to 17. 15. The mass differs both in the shape of its crystals and in its weight; seemingly as if the points or angular portions were wanting in some of the particles; precisely as we find to be the case with common salt. 16. This acid salt is very like common salt in taste. 17. It is contained in certain acid spirits; for example, in spirit of salt.

A POSTERIORI.

1. Acid spirits are capable of being condensed into a thick substance, shewing that when the water particles are driven off, the number of acid particles remaining is very large in proportion to that of the water particles.

2. Some acid spirits are susceptible of crystallization, for instance, the spirit of salt.

The flavour of the crystals is very similar to the saline flavour.

They are, however, supposed to involve a different form; which, unless we are mistaken, is no other than the triangular, according to our Theory of Compound Acid Crystals; in short, the form of the fourth kind.

Appendix, containing theoretical observations upon acid.

The square interstices between the particles of water in the natural position are full of subtle fiery matter, and the triangular spaces are full of acids; and it is plain therefore that the fiery matter cannot escape, because the triangular doors are blocked up. Hence, *firstly, the acid spirit is very moveable;* owing to the imprisoned subtle matter, which confers mobility. *Secondly. The acid liquid is very cold;* because the triangular interstices are destitute of the fiery matter; owing to the scantiness of which this liquid is colder than common water. *Thirdly. The acid spirit can never become ice;* for when water is converted into ice, the subtle matter issues from its cavities, and collects into granules or striæ; but here the doors are obstructed

by the acid particles, and consequently the fiery matter remains, and the water in this case cannot possibly take the form of ice: see our Theory of the Congelation of Water. *Fourthly. If the water have in it acids of different kinds,* either the first, the second, or the third, all which are triangular, *these acids will occupy no more space conjointly than separately.* Q. S. D.

A POSTERIORI.

Experience gives the same results. Thus,

1. Acid spirit is fluid like water.
2. It is very cold.
3. And it is totally inconvertible into ice; such at least is the case with the spirit of nitre, &c.; and the rule holds where the acid is of the simplest kind.

PART XIII.

THE THEORY OF NITRE; CONTAINING GEOMETRICAL AND EXPERIMENTAL DEMONSTRATIONS OF ITS PARTICLES, AND SHEWING THE MECHANISM OF THEIR SHAPE AND POSITION.

§ 1. *Description of the particles of nitre.*

Before we can obtain a knowledge of the particles of nitre, we must have a knowledge of the subtle fiery matter to which we have alluded above, and the particles of which are simply bullular, and capable of dilatation and compression under the influence of motion. In the absence of such a knowledge, our understanding of the inner structure of nitre will be but obscure. In the meantime, therefore, let the reader conceive the particles of the subtle matter to be, as we before said, simply bullular, that is to say, to consist merely of surface and nothing else, and to be susceptible of dilatation and compression; which, with several other properties, are detailed in our Theory of Fire; let him also conceive, according to our shewing in the same theory, that owing to the affinity between the particles and the equality of size between the superficial particles of both the subtle matter and the salt, the exquisitely fine volumes of the said subtle matter stick to the saline particles, and *vice versâ*. On all these subjects, however, see our Theory of Fire, § 5, where we have treated of the conjunction of soft and hard bodies with each other.

We think that the particle of nitre is angular in figure, and further, 1. *That in its inner part, or inside it, nitre has a volume*

FIG. 1.

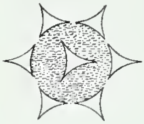


FIG. 2.

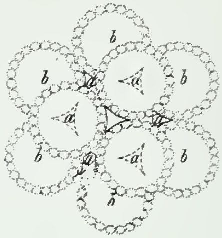
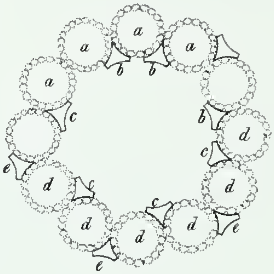


FIG. 3.



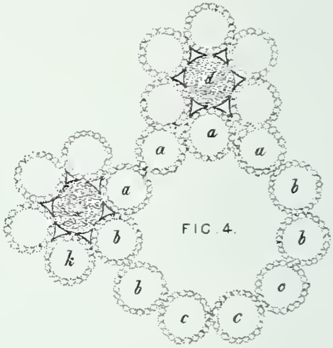
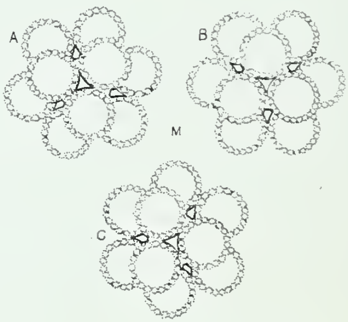


FIG. 4.

FIG. 5.



of subtle matter. 2. *That it has acid particles disposed on the outside, or on its surface.* 3. *These acids,* (like all salts and metals, according to the demonstration in our Theory of Fire,) *adhere to the subtle matter, they continue moveable, and in a manner fluid, even on the surface.* 4. But, (as in Plate IX., Fig. 1,) on the accession of as many water particles as can find a place around a particle of this kind, the acid particles arc transposed into a regular form, that is, into a form corresponding to that of the interstices between the particles, Fig. 1: see Fig. 2. Whence we regard *the particle of nitre as angular, containing a volume of subtle matter within it, and the acid particles being disposed on the surface, and by the circumpressure of the water particles transferred into the form that is proper to nitre:* see this form in Fig. 2. Having got the origin of nitre, in a word, having ascertained that it consists of acid particles disposed round a volume of subtle matter, and reduced by water particles to an angular position, we have both the exact form proper to it, and the exact number of the particles that compose it.

From this origin it follows, 1. That *a particle of nitre consists of fourteen acid particles,* joined together, however, conformably to the position of the water particles. 2. *Between the acids there are loculi or little spaces, into which the waters fit,* as in Fig. 1. 3. *Twelve waters will find room around one nitre;* which are just the same number as may be placed around one particle of water; viz., six round its periphery, thrce above, and three beneath: a particle of nitre therefore may be surrounded and covered by twelve particles of water. 4. *The diameter of the enclosed volume is equal to the diameter of a water particle;* which is thus demonstrated. If acid particles have found a place in the surface of a volume, the latter will of course be modified to correspond with the concavity and size of the former. Now the concavity of the acids corresponds to the convexity of the waters. Hence if fourteen acids enclose a volume, it will answer exactly to the concavity of the acid particles; or it will be of the same convexity as the water particles. From which we may conclude, that the diameter of the enclosed volume is equal to the diameter of the particle of water. 5. With respect to weight we have to observe, that *a particle of*

nitre weighs to a particle of water as 4 *to* 1; and we demonstrate it thus. One acid weighs to one water as 5 to 18, (see Part X., § 4, n. 3,) whence 14 acids are to 1 water as 70 to 18, or as 35 to 9, which is nearly as 4 to 1.

In short, we suppose that the particle of nitre consists of pure acids, mutually combined by the influence of water round an exceedingly minute volume of the fiery element. For if the acids adhere together, and the water particles intervene between them, they must necessarily be reduced to that form and position which is natural. Thus 14 acids occupying 14 interstices in the surrounding water, form one combined tissue, and inclose a volume of subtle matter answering to the size of their concavity, or what amounts to the same thing, to the convexity of the water. Therefore the diameter of the volume = the diameter of water, and consequently the weight of a particle of nitre is quadruple that of a particle of water.

The figure of nitre plainly shews, that it closely resembles common salt in many respects, and especially in the following: 1. *It is heavy,* like the particle of common salt. 2. *It is provided with spicula and points.* 3. *It displays an acidity and flavour,* something like salt. 4. *But as it has even more spicula than salt, it takes on a bitterness in taste;* bitterness being occasioned when the fibrillæ or papillæ of the tongue are pressed upon in a confused manner; &c.

A POSTERIORI.

1. Nitre is inflammable, and is easily resolved by heat; which is a sign that a volume of subtle fiery matter is latent within it.

When nitre is distilled, an acid spirit comes over; nearly all the nitre being convertible into the latter; which is a sign that nitre consists of acids ranged about a volume of the subtle matter.

2. Nitre is bitter to the taste; which indicates that it consists of a greater number of spicula than the particle of common salt.

Nitre is bitter in proportion as it is pure.

It may be used with food instead of common salt, but only in case of necessity.

Nitre has no odour in water; which is a sign that its particle is heavy; not less so than that of common salt.

Nitre does not effervesce either with acid or alkali; in which respect it resembles common salt.

§ 2. *The origin of the particles of nitre.*

A PRIORI.

From the preceding account, we may in some measure judge of the origin of the nitrous particle. There is hardly a spot on the surface of the earth, in which salt is not found, either entire, or divided into acids; and water particles and fire particles are equally universal. Now, on our principles, whenever the acids come in contact with a volume of subtle matter, they stick to its surface, and swim around it; and when water is present, they necessarily assume the angular position. With regard to the question of origin it is further to be observed, that,

1. *Nitre is generated in plants and vegetables.* For water particles, as well as saline, that is, acid particles and subtle matter, being carried upwards through the roots and stalks of plants, they will necessarily unite and naturally assume this form. When the water flies off, the residue is nitre. We therefore regard plants and trees as one source of this substance.

2. *Nitre is generated in soils and earths.* No demonstration is needed to shew how vast a concourse of particles, aqueous, igneous and saline, exist in the ground. One part or class of them is carried up into the air, another part is condensed by cold; another part is fixed by its particles coming in contact with each other, and becoming mutually interlocked: in short, the ground may be regarded as a womb for particles of all kinds, both those of water, those of essential salts, and those of nitre itself. And when by terrestrial distillation the salts are resolved into acids, and these are drafted about hither and thither on the back of the water, then the acids, the water particles, and the subtle matter, will inevitably be commingled and confounded, and as a matter of mechanical necessity, nitre will be formed. Remark, however, that, 1. *Nitre cannot be formed in a sterile*

soil; that is to say, in a soil where no large* salt has been separated; for in a soil of this description the acid particles are not present that are necessary to constitute the nitre. 2. *Nor can nitre be formed where the soil is too wet.* When the water is superabundant, the acid particles are separated from each other, and carried off in different directions before they can be formed into nitre; or even if the formation takes place, the nitrous particles are washed away. On this account wet soils are not adapted to generate nitre. 3. *Nor can nitre be formed in ground that has undergone the action of fire.* The effect of fire is to cause the acid and other saline particles to combine, and form peculiar lixivial alkalis; besides which, a portion of the acid particles flies off with the fire. Owing therefore to deficiency of acids, or else to their combination into lixivial alkalis, any soil that has been scorched by fire is ill adapted to produce nitre. 4. *Nor is any soil good for the purpose that is altogether unsheltered from the sun's rays, or the winter's cold;* for under both circumstances the acid is absorbed. 5. *The best soil is that which is under cover;* where the water is neither too abundant, nor always running, but rather stagnant, as under old sheds and houses.

3. *Nitre is formed in the air also.* We already know, from our Theory of Acid, that the particles of the acid of salt may accompany the bullæ or vapours of water; that is to say, rise upwards into the air in the interstices of the latter. And as it is evident, from our Theory of Evaporation, that subtle matter is enclosed in the vapoury bullæ, so it is no wonder that the acid particles are transferred from the interstices to the surface of the volumes of the subtle matter, and converted into nitre; as shewn in Plate IX., Fig. 3, where *aaddd* are waters formed into vapour, and *bce* are acids in their interstices. Now in this case, when the water particles are removed or separated, we see that the acid particles will admit of being transferred to the volumes of the enclosed element. In this manner nitre is mechanically formed in the air, but less perfectly than in the soil and plants. Whence we see that nitre is found in snow and rain, and that the earth is at any rate fertilized by the acid particles.

* "Large" here refers to the size of the particles of such salt.—*Tr.*

4. We also find that *saltpetre or nitre effloresces from calcareous stones and bricks.* This is owing to the stone abounding in saline particles, as lime, &c., in which there is much salt and much acid, and hence it is not surprising that the acids are brought out by various causes, and by the agency of water and the subtle matter, are formed into nitre; according to the theory propounded above.

We see then that nitre is generated in many ways, in fact, whenever acid particles, water particles, and the subtle matter, are properly commingled. And we have no doubt that there are far more sources of it than we have here particularized.

A POSTERIORI.

1. Nitre is found for the most part in plants and vegetables; which seems to shew that it is made and generated in them.

Bitter plants have more nitre in them than others.

Nitre is the chief of the essential salts; as we see in decayed herbs and trees.

2. A large quantity of nitre is found in earth, and may be obtained from it by boiling; which is a sign that nitre originates in the soil also.

Nitre is reproduced in the earth year after year; so that the saltpetre boilers often find a soil fertile that was formerly barren.

Nitre is not found in very wet places, nor are they calculated to generate it; inasmuch as superabundance of water washes the acid particles out of the soil.

Nitre is not found in places burnt up by fire, because in such places the acids have combined to form alkaline particles, and a portion of them is driven out by the fire.

Not much nitre is procured from any soil that has been exposed for a long time to the rays of the sun.

Nitre is not found in ashes; because in this case the acid particles are combined into the form of alkalis by the action of the fire.

Nitre is obtained in abundance in places protected from the sun and weather; as follows from what has been already said.

3. Nitre is found in rain water, especially in showers from

the south, and in the snows of spring; hence the lands are fertilized by showers.

Nitre exists in the air, as is evident from various plants, as Telephus semper vivus, ficus Indica, marsh lentil, and sea lentil, which throw out their roots into the air.

4. Nitre effloresces from calcareous stones and bricks, especially from such as are old; which shews that it is generated by the combination of water and subtle matter with the acids issuing from the sides of the stones.

Peculiar masses of nitre, like common salt in flavour, are often found in old lime.

5. It is said by some chemists, that nitre is generated when spirit of nitre is dropped into oil of tartar per deliquium.

§ 3. *The fluidity of nitre in water.*

A PRIORI.

It is sufficiently evident from their shape, that the particles of nitre will float about in water as in their proper element, and that in water they will have the same nature as the other kinds of salts. The reason of this is, that the external parts of the particle of nitre are manifestly formed for the reception of water particles. On this subject we have to observe, 1. That *twelve particles of water will find room round one of nitre:* so that wherever the particles of nitre may be in the water, they are surrounded by, and carry with them, twelve water particles. 2. *The former are transferred with the latter from the surface to the bottom, from the bottom to the surface,* and from one plane to another; in the same way as the particles of common salt, which are beset by only eight acid particles. 3. *Hence also the solution of nitre may be filtered through a bladder, and through blotting paper;* for since it is surrounded by twelve water particles, there are no points anywhere to impede its transmission. 4. *And hence it follows,* that if nitre be reduced to powder, *the pulverized particles appear fluid, like water,* because they are so surrounded by water particles that the points are concealed; thus the dust or granules of nitre exhibit a kind of fluid character. 5. *If the nitre particle be surrounded by twelve water*

particles, then we maintain that the weight of the volume so formed will be to that of a single particle of water as 16 *to* 1 *nearly.* For if fourteen acids together weigh to a water particle as 4 to 1, and if twelve more water particles be added, collectively they will be to the weight of a single particle of water as 16 to 1. 6. *When nitre is dissolved in water,* that is, when its particles become fluid, *the arrangement of the water particles changes from the natural position to one nearly approaching the triangular pyramidal.* For when any one particle of nitre is surrounded by twelve of water, the latter must be transferred from their natural fluid position into the arrangement which the spaces of the nitrous particle occupy, which is the triangular pyramidal. From this theory it follows, 7, that *the bulk of the water is increased but very little by the nitrous particles;* the increase which does take place being due to the accession of the water particles contained in the mass of nitre; as we shall shew in the sequel. 8. *When nitre is dissolved, the subtle matter occupying the interstices of the water must fly off:* so that the water foams; and this takes place if the square interstices of the natural position be disturbed by the accession of particles of nitre. 9. *Water becomes very cold by the solution of nitre;* for if the natural position be disturbed, and the subtle matter be thrown upwards, all the mobility that depends on the interflux of the fiery matter, will be destroyed, and the water will be rendered cold. 10. *A larger number of particles of nitre may find room in water than particles of common salt;* as will be seen presently.

A POSTERIORI.

1. Nitre will float with perfect facility in water, whence the latter appears to be its element, and the particles of the two seem mutually adapted to each other.

3. Nitre is purified by filtration through blotting paper; because no sharp point that might delay its passage, projects through the water particles that beset the nitrous.

Nitre is filtered through bladders.

4. The particles of pulverized nitre are fluent like water.

7. The solution of nitre is heavier than common water; which is a sign that the nitrous particles are contained within

the cavities or spaces that exist between the water particles; whereby the volume is rendered heavier.

8. When nitre is dissolved in water, a peculiar foam flies off; which indicates that the subtle matter is driven out of its spaces, and pushed upwards.

9. Water is rendered cold by dissolving nitre; a sign that the spaces between the water particles are occupied by the nitrous particles, and that thus the subtle matter is expelled from the same spaces, which occasions the cold.

10. A greater quantity of nitre may be dissolved in water, than of common salt.

§ 4. *The evaporation of the solution of nitre.*

A PRIORI.

The theory of the figure of nitre, and the theory of the evaporation of water, shew plainly enough how it is that the solution of nitre may be converted into vapours. From these theories it follows, 1. That *the nitre cannot accompany the vapour into the air.* For let *aa, bb, ccc,* (Plate IX., Fig. 4,) be an aqueous vapour or bulla, and *d* a particle of nitre; now the latter cannot at all have place amongst the aqueous bullæ, without projecting beyond the volume of vapour; in which case the equilibrium will be destroyed, the heavier part will fall down, and the little bulla of vapour will be broken. No entire particle of nitre then can possibly follow the vapour on high. Those particles that are found in the clouds and that fall in snow, are mere acids, that have been raised upwards, and been subsequently fashioned into nitrous particles; agreeably to what we have said above. 2. *Hence when a solution of nitre is evaporated, either by fire, or by the heat of the sun, only the aqueous particles fly off, and not the nitrous, which latter remain behind, and crystallize.*

It is to be observed likewise, 1. That *the water alone passes into vapour,* and that the particles of nitre remain with a smaller quantity of water particles. 2. *All the water contained between the volumes of the nitre may be driven off;* that is, until each nitrous particle retains only twelve water particles around

FIG. 6.

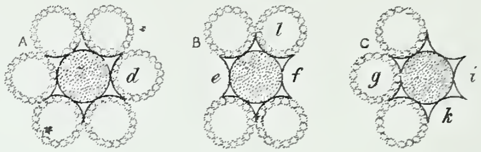


FIG. 5

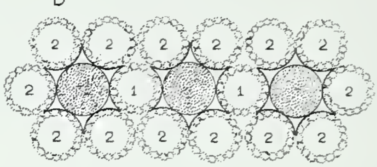


FIG. 8.

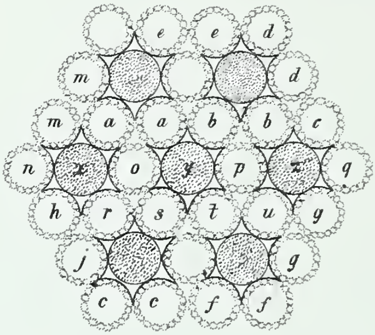
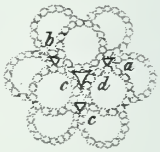


FIG. 9.

FIG. X.

FIG. Y.



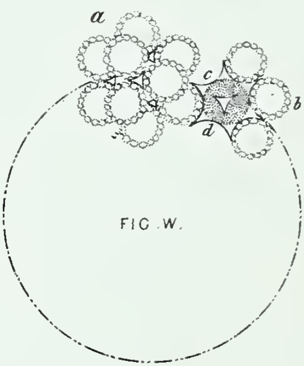


FIG. W.

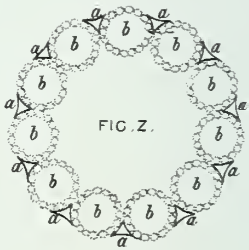


FIG. Z.

it, when it forms what we call *a volume of nitre.* Now when the particles of nitre are divided into such volumes, and all the intermediate water stated to be contained between them is evaporated, in such case we maintain that, 3, *a pellicle will be formed on the surface ;* and we demonstrate it thus. If the intermediate water between the volumes be deficient, then the water particles will of course run away in all directions from the loculi of the nitre, or from the volumes, into the vacant interstices, and when this takes place, the particles will become bound together; that is, two of nitre will be conjoined by one of water, or one of water by two surfaces of nitre; whereby a combination of particles will take place, and when this begins, it will be manifested on the surface by a pellicle: see Plate IX., Fig. 5. If the water of the nitrous solution be evaporated away, so that ABC are naked volumes inclosing nitrous particles, and if the intermediate spaces or intervals at M contain no water, then we say, that the water will necessarily run away from the volumes into the intervals, and the water particles of some other volume will fit into the vacant spaces, as at Plate X., Fig. 5, D, where three volumes of nitre are joined together at 1, 1; that is, two nitrous particles are united by one of water, which occasions the appearance of a pellicle.

A POSTERIORI.

1. Nitre may be crystallized by evaporation, just like common salt.

The water of a solution of nitre may be driven off by the sun, by fire, or by the air; and the nitre will remain behind. Whence it is clear, that the water alone passes off in vapours, and not the particle of nitre; which latter would break the bulla of vapour.

Nitre is more difficult to crystallize than common salt, and requires for this purpose a stronger fire.

2. When part of the solution is evaporated, a pellicle appears on the surface.

This pellicle or cuticle is a sign of crystallization, and indicates a deficiency of water in the interstices between the several volumes of the nitre.

§ 5. *The crystallization of nitre.*

A PRIORI.

The coincidence of our theory with the natural mechanism of the particles, is nowhere more evident than in the instance of crystallization, which takes place according to the geometrical rules of each particular figure. 1. *When there is a deficiency of water in a nitrous volume, it combines immediately with another volume by means of the water of the latter.* See Plate X., Fig. 6, where ABC are volumes of the particles of nitre, or single nitrous particles each enclosed in twelve water particles. Now if the water be deficient in quantity, the nitre particles are immediately bound together by the waters in another nitrous volume; thus, if there be no water particle in the cavity *e*, the latter is immediately connected with *d*, and *f* with *g*, and so on; so that two nitre particles adhere together by one water particle, as is clearly shewn in Fig. 5, D; and so on, one with another, both sideways, above and beneath, according to the mechanism of the figure. 2. *The first step of the crystallization is, for two or three nitres to combine in the solution*, according to Fig. 8, either in layers, or in hexagonal bases. In this figure (8) the dotted globules are the centres of the nitre particles, and the others are the water particles. In this stage of the crystallization we have to remark, *firstly*, that *the base of the crystal is hexagonal*, according to Fig. 8, and that it cannot be formed in any other way: for if the nitre particles be intermingled with the water particles, so that two of the former are united together by one of the latter, they will necessarily assume a hexagonal shape. *Secondly. The nitre crystallizes in layers*; that is to say, in lamellar bases. *Thirdly.* In this lamellar base, or in the plane, *the centres of the particles of nitre lie hexagonally*, as may be seen by the dotted globules in Fig. 8. *Fourthly. The particles of water in the horizontal plane are in the triangular position*; see Fig. 8. *Fifthly. The order of the particles of water is parallel to the hexagonal sides*, as *ee*, *ebc*, *zuf*, *hj*, *mxr*, &c.: so that the particles of water, conjointly with the nitrous centres, are in the triangular pyramidal position, and are parallel

with the hexagonal sides. *Sixthly. The plane that is above is also exactly similar to this;* that is to say, the particles of nitre are superimposed in the same way as in this plane, so that the mass itself, or the volume of the particles of water, is in the pyramidal position. Here again we must observe, 1. that *the upper nitre particle is necessarily placed on the joinings of the lower plane,* or that the upper plane is fitted into the lower plane, as in Plate X., Fig. 8: for of necessary consequence, the upper nitre particles are lodged in the joinings *aa, bb, cc, dd, ee, ff, gg,* so that in Fig. 9, the lowest part of the nitre *m* is applied to some one of the joinings, either at *aa, bb,* or *cc*; and the apex *n* is also inserted into the interstice between three particles. 2. These particles are likewise beset by water particles like the first, and when united, they are associated together in the same plane. 3. *It is the same thing whichever apex is inserted into the interstices,* since the nitre particle is uniform on all its sides: and so the insertion of one plane into another takes place by the insertion of the points *m* or *n* into the interstices of the three particles that are under them. 4. *The insertion of the nitre particles may take place at aa, bb, cc, dd, ee, ff,* Fig. 8, *but not at any other parts;* because the other parts are occupied already by the points of the particles of nitre, but the former have vacant spaces for their reception. This is a necessary result of the mechanism of the aqueous and nitrous particles, and consequently of the geometrical law of crystallization.

It likewise follows, that the crystals of nitre, formed as they are on this law and according to this mechanism, have, 1, *a hexagonal figure.* 2. *They are divided into horizontal lamellæ,* that is, into strata upon strata, all of the same character and figure. 3. *The water particles contained therein, and the centres of the nitre particles, are in the fixed triangular pyramidal position.* 4. *The sides of the hexagonal crystal are partly perpendicular and partly oblique:* which is thus *demonstrated.* If the upper nitre particles be applied to the interstices of the lower, they will of necessity be applied in the junctures and points of union *aa, bb,* and also in *ee, ff, gg,* and so on, about the surface, at right angles with the horizontal plane, whereby the crystal will rise up perpendicularly. 5. *It also takes place*

obliquely at an angle of 60°, *and terminates in a summit.* For if the crystallization be not effected in the outward parts *ee, gg, ff,* on account of the water, but only in the inward places, as *aa, bb, cc, dd,* and so on, then there will be an obliquity of the plane of about 60°, and an apex or lesser plane in the middle. This obliquity may be demonstrated by trigonometry. Thus it appears by the analytic calculus, that the side which subtends the oblique angle is equal to the semidiameter, whence the angle is of 60°, that is, *of the plane itself.* 6. But when a fresh crystallization is added, an increase takes place in the apices as well as in the sides. 7. Since the substance is thus divided into horizontal layers, it follows, that *one perpendicular plane ends in particles of water, but the next in hollow particles of nitre;* the termination at the surfaces being alternately in water particles and nitre particles, and so on, up to the summit. Hence we have the mechanism of the crystallization of nitre, which from the figures which we have taken, cannot be any other than we have here described it.

As to the numerical proportions between the water particles and nitre particles, it follows from the mechanism of the figures, that *three particles of water are required to one of nitre.* Let Fig. 8 represent the crystal, the dotted particles are those of the nitre, and *nopqhrstwg* are those of water. Now we maintain that three particles of water correspond to one of nitre; thus *nhr* to the nitre particle *x*; *ost* to *y*; *pug* to *z*; and so on with the nitre particles of another row; in the same way about the nitre particles in the upper planes. Wherefore the number of the water particles in the crystals is to that of the nitre particles as 3 to 1. 2. In one nitre there are fourteen acids, and *hence the number of the acids is to that of the waters as* 14 *to* 3.

It is also to be observed, 1, that *the crystallization of nitre varies greatly according to the different modes in which it takes place.* For instance, 2, *if the water be very scanty;* for in case of deficiency of water, some spaces will be denuded that ought to be filled with water particles, and the crystallization will be confused. 3. *If the water be too abundant,* the spaces of the nitres will be occupied here and there by the waters, and thus the figure will be in some measure different. For if the water be too plentiful, it will occupy some parts even in the side of

the crystal, instead of the nitre particles. 4. *If saline particles of any other kind be intermingled with the nitrous*, and crystallized with them, if, for example, this is the case with the particles of common salt, or of alkaline or vitriolic substances, then the crystal will vary both in shape and weight; because the particles of common salt have a square shape, but the nitrous are angular, and when the two crystallize together, the form of the crystal is altered. The result again is different, if these particles of common salt are of various kinds, though all of a square form. 5. But if they are redissolved, filtered and evaporated, they can be separated from each other, &c.

A POSTERIORI.

1. Nitre is crystallized by evaporation; which is a sign that the crystallization begins from deficiency of water, and is nothing more than the conjunction of two nitre particles by means of the same water particle, &c.

2. The base of the crystal of nitre is hexagonal, and generally of a very regular form.

The six sides are mutually parallel, and perpendicular to the base.

In the upper part, these planes are bent at an angle of nearly 60°.

They end either in a point, or in a small plane parallel to the base.

Some chemists have observed the composition of nitre to be lamellar; which is a sign that the particles of water are arranged in the triangular position, or in such a manner as the shapes of the nitrous and aqueous particles require when united together.

3. Distillation proves that there is a great quantity of water particles in a mass of nitre: see § 10, where the experiments tend clearly to establish that such a mass contains three waters to one nitre.

4. The particles of nitre, of alkalis, and of common salt, may be crystallized together.

And they [the crystals of nitre?] may be improved by repeated crystallization.

The more frequently nitre is crystallized, the more like it

becomes to common salt: and saltpetre is converted into pure nitre.

If too much water be present, crystallization will not ensue.

If very little water be present, the crystallization will be confused.

When the water is in moderate quantity, the crystallization is regular.

More time is required for the crystallization of nitre than for that of common salt.

§ 6. *The weight of the crystals of nitre.*

A PRIORI.

The weight of the crystals of nitre may be ascertained by the same theory; for when once the position of the particles and the relative number of waters and acids are known, the weight is easily inferred. Hence it follows, 1. That *the weight of a mass of nitre is to the weight of the same bulk of water as* 11 *to* 6. *Demonstration:* According to the foregoing theory, the space of the particles of water in the natural position is to the space of the same in the fixed triangular pyramidal position as 512 to 483; or reciprocally, the weight of a volume of the former is to that of a volume of the latter as 483 to 512. Let therefore the weight of the water in this pyramidal position = 512, and according to the demonstration, let there be three waters to one nitre; then a fourth will have to be deducted from the weight; viz., 128 from 512; the remainder, 384, is the weight of the water in the mass of nitre. But since, by the theory, each nitre carries fourteen acids around it, and the weight of one acid is to that of one water particle as 5 to 18, hence the fourteen together give the proportion of 70 to 18, or of 35 to 9. But as there are three waters for one particle of nitre, the weight 384 is increased in the following proportions; $9 \times 3 : 35 :: 384 : 497\frac{7}{9}$. If this latter number be added to 384, the weight of the entire mass of nitre will be obtained $= 881\frac{7}{9}$; whilst the weight of its bulk of water is 483: these proportions in smaller terms are as 11 to 6, nearly. 2. But as the water occasionally besets the surface of the crystal, and there occupies the

vacant loculi, so *an increase of weight may ensue from the accession of superficial water,* which is increased in a moist atmosphere, or when the mass is powdered into granular dust. 3. *The weight likewise varies in different kinds of crystallization.* For if there be much water in the saline mass, it must necessarily weigh less. But if the nitre be crystallized with some other kind of salts, for instance, with common salt, the weight may be either augmented or diminished, as the case may be, by the circumstance. Hence we are speaking of none but the pure and genuine crystals of nitre, the weight of which is to the weight of an equal volume of water as 11 to 6.

A POSTERIORI.

1. Nitre weighs to water nearly as 5 to 3.

But the weight varies according to the different kinds of nitre.

§ 7. *The solution of the crystals of nitre in water.*

A PRIORI.

The crystallization of nitre will enable us to form a tolerably correct idea of its solution, for whilst the former takes place from defect of water, the latter is due to its superabundance. The following are the results of this induction. 1. *The crystals of nitre are dissolved in layers or lamellæ.* This is because the composition or crystallization takes place in *lamellation,* and so the solution necessarily also takes place in the same direction, and according to the same planes. 2. *Nitre is much more soluble in water than common salt.* Since one layer is combined with another by the mere insertion of the apices, one plane can be easily raised up from another, or be pushed off obliquely, whereby the particles are separated. The reason why nitre is more soluble in water than common salt, is, that the particles of water in the latter must leave their connexions in a right line, but in nitre they can leave both in right and oblique lines, or in any way whatever in which the removal or elevation can take place. Nitre may therefore be dissolved by the mere humidity of the atmosphere.

A POSTERIORI.

1. Saltpetre or nitre liquifies in common water.
2. Nitre is liquifiable in moist air, as in a wine cellar.

And it is possible to filter it through a bladder, and so to purify it.

3. A longer time is required for the crystallization of nitre, than for that of common salt.

§ 8. *The bulk of a solution of nitre.*

A PRIORI.

When nitre is dissolved, it is manifest that the bulk of the water is increased thereby. Hence, 1. *If a mass of nitre be dissolved, the volume of the water is increased by as much space as the mass of nitre occupied before it was dissolved;* which is thus demonstrated. If crystals of nitre be placed in water, it is clear that they will occupy a space equal to their bulk, and that the volume of water will be at once augmented in this exact proportion; so that if the space of the volume of water $=5$, and that of the mass of nitre $=1$, the volume of the solution will $=5+1=6$. 2. *When the mass is dissolved, a great part of the water occupies the fixed triangular pyramidal position,* the number of which may be obtained by the proportion of 4 to 13. For in a mass of nitre there are three waters to one nitre; but in a volume of solution, twelve waters may beset one nitre; and hence we maintain that the number of the surrounding particles may be obtained by the proportion of 4 to 13. Thus the space of the mass of nitre $=b$ to $\frac{13\,b}{4}$. Now let the volume of the water $=a$; and let the ratio of the space of the fixed triangular pyramidal to that of the natural position be as c to d; then the remainder of the volume, which is not transferred into that position, will $=a+b-\frac{13b}{4}=\frac{4a+4b-13b}{4}=\frac{4a-9b}{4}$. Let $\frac{13b}{4}$ be the part converted into the pyramidal position by means of the ratio d and c, and if $\frac{13b}{4}$ be converted to $\frac{13cb}{4d}$ for the space

occupied by the particles reduced to the pyramidal position, to which add the difference already mentioned $\frac{4a-9b}{4}$, then we shall obtain $\frac{4ad-9bd+13cb}{4d}$ as the bulk of the solution of nitre, which, if compared with the whole volume $a+b$, will afford a ratio in smaller terms as $4ad+4db$ to $4ad-9db+13cb$. *In numbers,* let the volume of water $=10=a$; and the space of the mass of nitre $=1=b$; and the ratio of the spaces of the pyramidal and natural positions, c and d, be as 483 to 512; then $4ad+4db=22528$, and $4ad-9db+13cb=22151$. Therefore the whole volume, or space of the water and mass together, when the nitre is dissolved, diminishes until it gains the above-mentioned proportion, viz., of 22528 to 22151, or of 60 to 59 nearly. 3. *The actual particles of nitre do not occupy more space than is usual with the particles of water. Demonstration:* Since the internal volume of subtle matter is of the same diameter as a particle of water, and is pressed on all sides by the twelve water particles in the twelve cavities or spaces, it follows that one nitre particle cannot take up more room than one particle of water. Hence a solution of nitre is not much increased in volume by mere nitres, but only by waters: for the change in the position contracts the volume, and brings it into a smaller compass quite as much as the particles of nitre increase it.

A POSTERIORI.

1. When nitre is dissolved in water, the volume of fluid is increased.

The increase of volume is equal to the space of the mass.

The weight of the volume of the dissolved nitre is also increased.

2. Water is cooled down by dissolving nitre; which indicates that the water particles have been a little changed in their position.

§ 9. *The weight of the solution of nitre.*

The mechanism of the figure of nitre gives the following consequences. 1. *If a mass of nitre be dissolved in water, the*

weight of the volume will be increased by the exact weight of the nitre. 2. *A volume of solution of nitre will weigh just as much more than the same volume of pure water, as is equal to the separate weight of the nitre particles contained in the mass.* For example, if in a mass of nitre there be three waters to one nitre, and the weight of these waters be 27, and that of the nitre 35; then the weight of the volume will be increased by 35; that is to say, by the weight of the nitre, but not by the 27, or by the waters, for the latter go to increase the volume of water. 3. *A mass of nitre may be dissolved by water, until the numbers of the water particles and nitre particles are to each other as* 18 *to* 1. *Demonstration:* If one nitre be occupied by twelve waters, and if there be at least six waters between these volumes, then the proportion of the nitre to the waters will be as 1 to 18. 4. *If there be more nitre in the water, no larger quantity can be dissolved, but the overplus will separate and crystallize,* owing to the emptiness of the interstices between the volumes. 5. *A weight of water* = 135 *will dissolve a mass of nitre* = 62: which is demonstrated as follows: If there be eighteen water particles to one nitre, three of them will be required for the mass of nitre; the remainder therefore is 15. The joint weight of three waters and one nitre is 62. Now if the water particle = 9, and the acid particle = $2\frac{1}{2}$, the 15 waters will = 135; so that a weight of water = 135 will at the utmost dissolve a mass of nitre = 62. 6. *If a volume of pure water, and a volume of solution of nitre, differ in weight, the difference will = the weight of the particles of the nitre.* For since the latter occupy scarcely any space on their account in the water, they will increase the weight but not the volume; and so the additional of weight will = the weight of the nitre particles. 7. *The difference of weight between the volumes, with the addition of $\frac{27}{35}$ of this difference, will give the weight of the crystals of the nitre in the volume.* That is to say, if there be two volumes, one of pure water, and the other of solution of nitre, equal in bulk, but differing in weight, for example, to the extent of five ounces; in this case we say that by adding $\frac{27}{35}$ to this difference, we shall obtain the weight of the mass of nitre contained in the volume of solution; namely, $8\frac{6}{7}$ ounces of crystals. For if the difference be equal to the weight of the particles of nitre, and if three waters be required

for each nitre in the mass, the proportion of the weight of the nitre particle to that of the three waters will be as 35 to 27. Hence by calculation, an addition of $\frac{27}{35}$ must be made for the water in the mass of nitre; consequently 5 must be increased by $3\frac{6}{7}$; the sum total therefore, $5+3\frac{6}{7}=8\frac{6}{7}=$ the weight of the crystals of nitre. 8. *If the proportion of the particles of water and nitre in the solution be less than* 18 *to* 1, *the part that is deficient in waters will crystallize.* For example, let the proportion of nitre be as 1 to 12, which it may be in case of evaporation; in this case a pellicle will form, and a part of the solution crystallize; whilst the remainder preserves the proportion of 18 to 1. For if the water be so deficient in quantity that the intervals between the little volumes are not filled with waters, (as may happen from evaporation,) it will run down from the cavities or loculi of the nitre into the empty intervals, and a portion of the nitres will crystallize. 9. *If the solution be driven off in vapours, and put aside in a wine cellar to crystallize, and if the crystals weigh* 3, *and the remaining ley* 6, *then we say,* firstly, *that in the residual ley there will be* 18 *waters to each nitre.* Secondly. *The weight of the ley will be to that of pure water as* 197 *to* 162. Thirdly. *Some nitre will still remain in the ley, and will be capable of being crystallized;* the weight of it being to that of the ley as 62 to 197. Fourthly. *Before the evaporation and crystallization take place in the solution, the number of waters to nitres is as* 70 *to* 8, *nearly.* The demonstration is as follows: The weight of the crystals is the half, and the proportion of the waters and nitres in the ley is as 18 to 1; but in the crystals, as 3 to 1. The weight of the proportion of the ley, 18×9, with 35, makes 197. Half of this weight in the crystals is $98\frac{1}{2}$. Now since the proportion of the particles in the crystals is as 3 to 1, or the weight is 62; hence as $62 : 1 : 98\frac{1}{2} :: 1\frac{73}{124}$, for the number of the nitre particles; and for that of the waters as $62 : 3$, so is $98\frac{1}{2} : 4\frac{95}{124}$. Now add $18+4\frac{95}{124}=22\frac{95}{124}$, and add $1+1\frac{73}{124}=2\frac{73}{124}$. The proportion of the particles, therefore, is as 941 to 107, or as $70\frac{38}{107}$ to 8.

§ 10. *The distillation of nitre.*

A PRIORI.

The distillation of nitre affords us a more complete idea of

its internal composition, than any other process. When its composition is examined, we have the following results: 1. *The particles of nitre are reduced by a distilling heat into the small volumes already mentioned;* in which case the nitres float about in mutual separation from each other, each accompanied by its twelve waters. 2. When the mass is liquified, *these volumes are impelled into most rapid motion around their respective centres.* 3. By this means one aqueous particle is sundered from another, and the compact surface consisting of acids is broken up. 4. *A certain swelling is likewise occasioned by the fire,* and thus, by the motion, as well as by being deprived of its waters, the particle of nitre is broken in pieces and resolved into acids. 5. When this takes place, the water comes over with the acids in the same way as with the acids of common salt; *and so we have the acid spirit of nitre.* 6. It is also to be observed, that *when the nitre is divided into granules, and mixed with bole, much superficial water is attracted;* for in small bodies the surface is greatly increased in proportion to the bulk; and the loculi or spaces and the superficial water, are in proportion to the surface. 7. This superficial water is nothing but phlegm, devoid of acid.

1. *During the distillation of nitre, phlegm comes over, which will weigh to the mass of nitre as* 9 *to* 62. *Demonstration:* The phlegm is nothing more than the superficial water, when the mass is disintegrated, and reduced to smaller parts; for when divided, it has more surface in proportion to the bulk than when it is entire. Hence it follows, that when a mass of nitre is divided into granules, it is increased by at least half a particle of water, since there are three waters in the mass to one nitre. If the weight of one water $=9$, then three $=27$; and as the nitre particle $=35$, $27+35=62$. Hence the proportion of the phlegm to the mass of nitre may be taken as 9 to 62, but it varies if the nitre has become more humid by division. 2. *An acid spirit then passes over, which will weigh to the mass of nitre as* 35 *to* 62. *Demonstration:* Let the number of waters in the mass be to that of nitres as 3 to 1. Or let the number of waters be to that of acids as 3 to 14: but half a water has already escaped in phlegm; so that $2\frac{1}{2}$ waters remain to 14 acids; and according to the theory of evaporation, the waters are converted into bullæ and vapours, in the inter-

stices of which the acids are contained, as in Plate X., Fig. Z, where *bbbb* are waters transposed into vapour bullæ, and *aaaa* are acids in the interstices of the waters. Since therefore, as many acids follow as can find room, that is, as many acids as there are interstices, hence they are twice as numerous as the waters, because the interstices are double the number of the waters. Hence of necessity, the acid particles accompanying the watery bullæ are twice as numerous as the waters. Let us therefore take the highest quantity, viz., when the acids are twice as numerous, now in the mass of nitre there remain $2\frac{1}{2}$ waters to 14 acids; 5 acids correspond to $2\frac{1}{2}$ waters. As one water weighs 9, $2\frac{1}{2}=22\frac{1}{2}$. The weight of an acid compared to that of a water taken at 9, will be $2\frac{1}{2}$; therefore the five accompanying acids$=12\frac{1}{2}$, and $22\frac{1}{2}+12\frac{1}{2}=35$. The mass itself is $27+35=62$. Hence the proportion of the acid spirit which comes over, to the mass of nitre, is as 35 to 62. 3. *The phlegm and spirit together, or all that can come over, will weigh to the mass of nitre as* 22 *to* 31. If the phlegm 9 be added to the spirit 35, we have 44, which is to the mass of nitre as 44 to 62, or as 22 to 31. 4. *The caput mortuum that remains behind weighs to the mass of nitre as* 22 *to* 62: which is thus demonstrated: If all that had passed over$=44$, when the additional half particle of superficial water which escaped in phlegm$=4\frac{1}{2}$ is subtracted, the remainder will be $39\frac{1}{2}$, which deducted from 62, leaves $22\frac{1}{2}$; so that the caput mortuum will be as $22\frac{1}{2}$ to 62. 5. Thus the spirit of nitre weighs more than common water, or *its volume is to that of water as* 14 *to* 9: which is thus demonstrated: As two acids accompany each water, so one water with its two acids will weigh $9+5=14$. But the acids only have place in the interstices, and hence the volume is not increased, but only the weight of the volume; therefore the volume of acid weighs to the volume of water as 14 to 9. 6. When it weighs less, there is consequently less acid intermingled with it, and some phlegm. 7. The vapour of the acid is of a red colour, as will be demonstrated in the proper place. 8. The caput mortuum of nitre is alkaline, as will be seen in our Theory of Alkaline Ley, where we shall give the mechanism of the transmutation of acids and salts into lixivial alkalis by the agency of certain particles that arise from the fire; whence

moreover its weight, or the weight of the caput mortuum, may be increased by the presence of fire.

A POSTERIORI.

1. A less strong fire is required for the distillation of nitre than for that of common salt; which is a sign that the acids of nitre are more easily loosened than those of common salt. In fact the acids of nitre are separated by the mere tumescence of the mass, but those of common salt by nothing short of fracture and motion.

2. In the first instance a white liquid comes over, and subsequently a red one.

The white liquor is nothing but phlegm, but the red is the acid spirit.

3. In the distillation of nitre, the material tumefies and fills the retort.

1. When nitre is distilled, phlegm comes over first: after the phlegm, an acid spirit, called spirit of nitre: after which, a caput mortuum remains behind; this caput mortuum is a lixivial alkali.

All these circumstances shew, that the nitre contains a great quantity of waters as well as of acids; part of which, when separated from the body of the nitre, escape by themselves in the shape of water or phlegm, and part escape in combination, for instance, in the shape of water united with acids, forming acid spirit.

3. A mass of nitre yields two-thirds of acid spirit.

The phlegm and spirit together weigh to the mass of nitre as 3 to 4. This coincides with our calculation; for 3 to 4 is nearly as 22 to 31; thus $3 : 4 :: 22 : 29\frac{1}{3}$; which is no great discrepancy. The difference may arise from a variation in the quantity of the water; for there is more water in nitre that has been well pounded than in whole nitre, and more where the powder has been long exposed to the air; to say nothing of other cases.

From the principles here given it may be seen, that the whole mass of nitre may be distilled into acid spirit, provided only a sufficient quantity of water be present: for there is

nothing in nitre but water and acid, united with a subtle matter that flies off. And this is in some measure confirmed by experience. But as the nitre is crystallized in conjunction with waters, it would seem that it cannot yield more acid spirit than shall be to the mass as 35 to 62, unless an additional quantity of water be supplied; which, however, cannot ensue from exposure to the air, as in the distillation of common salt; because the acids of the nitre are combined into a peculiar alkali by the agency of the internal subtle matter.

The acid spirit of nitre is heavier than common water.

The spirit of nitre is a very strong acid, in which nearly all the metals are soluble. In combination with oil of vitriol, it forms aqua fortis. See our Theory of Acid, and of Metals.

§ 11. *The calcination of nitre.*

A PRIORI.

The calcination of nitre is effected by adding to it sulphur, charcoal, &c., whereby the nitre is made to detonate, as we shall see presently. But when a mass of nitre is melted by fire, it would seem that the division which takes place is not the minutest of all, but is rather a division into parts comparatively large; the mass being divided into a powder, each constituent of which consists of from three to five nitres together with their proper waters: the mechanism of which will be given in our Theory of Fire and of Alkalis. Hence we have to remark, that, 1. *By the agency of fire, a mass of nitre is divided into grains or globules, each of which is a compound of several nitres.* 2. *These granules are covered, that is to say, the powder is beset by water particles,* and by their assistance the granules are rendered mobile and fluid. 3. *Hence the fire is not put out by the water, or even so much as hindered, because the waters adhere to the saline cavities.* The reason is, that the waters cannot be converted into vapours, or carry away the fiery matter, as is the case when water in a state of division comes in contact with fire; for in the present instance, the water adheres to the nitres, and is in a manner held captive. 4. The detonation and explosion of nitre cannot be explained until we have learnt the nature

of fire, oil, sulphur, and other substances: nevertheless we shall give the experiments.

A POSTERIORI.

1. A white flame appears when nitre is calcined.

2. Nitre melts like a metal under the action of fire, and becomes exceedingly hot.

3. Melted nitre boils when it is stirred about with a pin or rod.

4. When a red-hot coal is dropped into melted nitre, it boils, effervesces, crepitates, and drives the coal about in a circle, and the coal reaches a white heat.

Melted nitre will consume many coals in this way.

If the coal is not red-hot, the melted mass will project it into the air.

5. When the detonation or deflagration is at an end, and the coal consumed, the nitre is converted into bullæ.

When this material cools, it will be found to be as hard as a stone, yet still it is soluble in the damp air of a cellar: it is, in fact, a lixivial alkali similar to oil of tartar, and of a similar taste.

If this alkali be left for a long time, it at last loses its alkaline character, and ceases to effervesce with acids.

6. Nitre, charcoal, and sulphur, make gunpowder, in the proportion of five parts of nitre to one of sulphur.

7. When gunpowder is kindled, it occupies 222 times its former space.

§ 12. *The vegetative power of nitre.*

A PRIORI.

Salt of nitre occupies the principal place among essential salts, both because it has the character of an essential salt, and because it is composed of three materials, viz., water, salt, and an internal subtle fiery matter. Its peculiar fitness for entering into vegetation will be seen in what follows. 1. *The subtle fiery matter is the internal material of nitre.* 2. *On the surface of this matter there are acids,* transposed into the proper position

by the waters that convey the acid with them. 3. *There are loculi or cells on the surface for receiving the waters,* twelve of which may therefore beset one nitre, and find place around it. 4. *The matter of oil may inhabit the same loculi,* whether its particles be alone, or whether there be particles of oil and water alternately. 5. *Volumes of the fiery matter may be kept in the same loculi,* and so vary the volumes of nitre. 6. Whether there be water, or oil, or subtle matter, in the loculi of the nitre, *a second nitre may combine with it;* feebly, however, if water be present; but more firmly if oil or the subtle matter occupies the spaces. 7. *Any saline cube may adhere to a single particle of the kind,* that is beset by waters, or by oil. 8. *The particles of common salt may so adhere.* 9. Hence by the assistance of waters, oils, volumes of subtle matter, particles of common salt, saline cubes, acids and nitres, *the particles of nitre may combine to produce the most diverse forms,* and may be mutually attached to each other, feebly by water, but very closely by oil. 10. *Nitre crystallizes in hexagons,* as demonstrated above. 11. *Nitres will combine together in right lines, both perpendicularly and horizontally.* Plate X., Fig. Y, is a particle of nitre, beset by waters or oils. Now we say that particles of the kind may crystallize upwards in threads, if another nitre be applied to the top of the preceding particle Y, as in Fig. X, where the apex *e* is to be applied to the summit *d*, then another particle to the summit of the preceding one, and so on *ad infinitum.* 12. *Filaments of nitres may also effloresce obliquely;* if the apex *e* be inserted into the interstices of three particles at *a*, *b*, or *c*; whereby the elevation and extension of the thread will take place at an angle of 90° either to the left or to the right, just suitably to the arrangement of the tubes in plants. 13. *In this manner tubes or pores may be generated parallel to the horizon,* because one nitre particle may be conjoined with another by simple application. 14. *Nitrous particles also admit of being combined in a circular form;* as when one is applied obliquely to the side of another: see Plate X., Fig. W, where the nitre *a* is combined with the nitre *b* by a water, an oil, or a volume of subtle matter, and especially so in case there be no water in the loculus or cavity *d* or *c*. A single nitre particle, therefore, in a plant, may crystallize as part

either of a hexagon, or of a triangle, or of a circle, or of a hyperbola, or of some other form. We may thus see, that no shape is so suitable as nitre for combining into vegetable forms; but on this subject consult our Mechanical Chemistry of Vegetables, where we shall shew that the particles or essential salts being given, crystallization necessarily takes place in this form or the other. See also some remarks on the same subject in our Theory of Silver, where we shall speak of the Philosophical Tree.

A POSTERIORI.

1. Nitre is generally found in plants and herbs, especially where bitterness is present.

2. Nitre fertilises the land to a very great degree.

3. If eight parts of nitre be distilled with five parts of vitriol, a caput mortuum is left that is capable of assuming various forms.

FIG. 1.

FIG. 2.

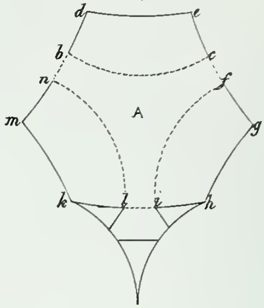


FIG. 4.

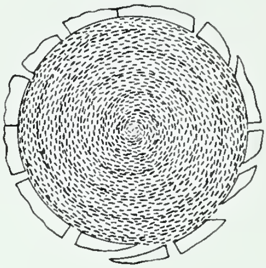


FIG. 3.

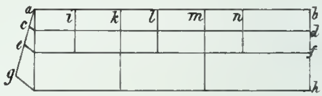
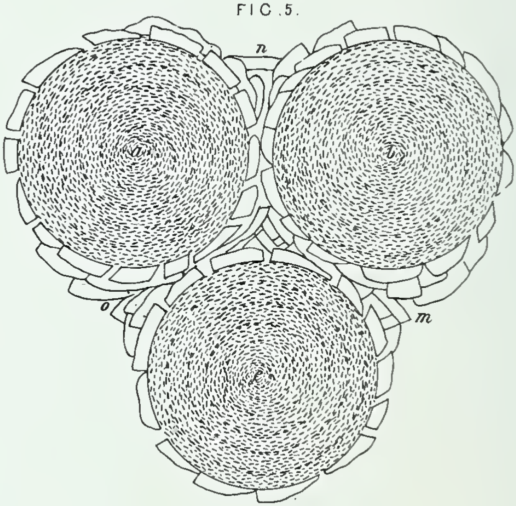


FIG. 5.



PART XIV.

THE THEORY OF OIL AND OF VOLATILE URINOUS SALT; STATING THE EXPERIMENTS ON THESE SUBSTANCES, AND BRIEFLY EXPLAINING THE GEOMETRY OF THE PARTICLES.

§ 1. *Description of the ramenta of salt.*

We are now about to treat of oil and of urinous salt; not, however, with the design of giving the entire theory of either, which indeed would occupy considerable space, but rather of presenting a slight outline of the origin and nature of these substances, in order that the reader may the better comprehend what we have to say respecting sulphur and vitriol. We shall, therefore, defer till a later period the full treatment and geometrical consideration of the particulars about to be mentioned concerning oils and urinous substances.

If the genuine figure of salt be examined, as it originates at the bottom of the sea, and which figure we have demonstrated theoretically, it will be found that at the very first, in the cradle of its earliest formation, it is by no means precisely such as we have described it, but has certain acuminated and fine portions connected to it in addition. Thus, in its earliest state, the acid particle is not exactly according to Fig. 1 (Plate XI.), but according to Fig. 2. For if the figure of acid or common salt answer to the figure of the interstices of water, then of necessity certain exquisitely thin or lamellar portions must exist at the sides, which will be abraded or rubbed off by the least motion or friction. It is to be observed, 1. That when common salt or acid is first produced, its sides are acuminated, as in

Fig. 2, at *gh, de, mk,* &c. 2. After it has been dissolved, agitated, and crystallized several times, these fine, sharp or lamellar parts *ghfi, debc, nlmk,* will be broken, and gradually abraded. 3. When this happens, the true acid is left, as in Fig. 1. 4. The fracture of these thin layers or ramenta takes place mechanically at the edges of the particles; for as salt consists of hard particles of the fifth and fourth kinds, there is no room in the exquisitely thin extremities of which we have spoken, for the fifth order of particles, but only for those of the fourth: and hence the former must stop at once at the joinings *fi, bc, nl;* the other parts, therefore, which consist of a finer matter, viz., of the particles of the fourth kind, will be torn away at this spot. 5. These ramenta consist of hard particles of the fourth order, the layers not being thick enough to afford room for those of the fifth order. 6. The shape of the ramenta is triangulo-lamellar, like *abgh* in Fig. 3. 7. They are susceptible of being again broken into smaller ramenta, by division in the middle, either longitudinally or laterally; thus they may be divided at *i, l, e,* or *k,* or into *cl,* or *cd,* or at *iklm* or *n.* 8. There are, therefore, ramenta of different kinds, large and small.

And thus it is clear, that while salt is recent, as it lies in its cradle, and has just originated, it has sharp sides answering exactly to the figure of the interstices of water; but when these acuminated parts are abraded, the genuine figure of true salt is produced. It is also plain that these acuminated lamellæ are themselves cavo-triangular; a necessary consequence of their origination in the interstices of water.

§ 2. *The origin of the particles of oil.*

As, then, the ramenta mentioned above are composed of the hard material of the fourth kind, so they adhere to the soft fiery particles in the same manner, and in the same proportion, as do the saline particles. It is demonstrated in our Theory of Fire, that saline matter will adhere, and very tenaciously too, to the volumes of the particles of fire; wherefore these ramenta likewise, when they come in contact with the subtle fiery matter, stick to it as to a mould, and thus form a new particle, which is *oil.* It is also to be observed, 1. That when these saline ramenta

meet with the subtle matter, they group themselves around it, stick to it, and form a surface or crust; thus constituting a fresh particle of oil, as in Plate XI., Fig. 4, where the subtle matter is in the interior, with ramenta of different kinds on the surface, and both together compose the oil particle. 2. The ramenta stick pretty closely to the subtle matter, in the same manner as the acid particles that constitute nitre. 3. The particles themselves may be reciprocally connected by mutual contact, or if not connected, they nevertheless adhere. 4. It is very difficult to separate these particles, unless by fire. 5. They contain the same matter in the inside as the particles of nitre and of water: there is however this difference, that nitre particles are surrounded by acids, but oil particles by saline ramenta; the shape also of the former is angular, while that of the latter is nearly round. 6. Ramenta of very different sizes may beset a single particle, as shewn in Plate XI., Fig. 4; in one surface large and small ramenta may be joined together, and not admit of separation from each other, unless by fire, or the lapse of time. 7. The dimension of the oil particle is equal to that of the water particle; that is to say, *its diameter is equal to that of the water particle.* For the ramenta are excavated to the dimension and convexity of the water particle, and the enclosed volume of subtle matter is necessarily formed to the same model. 8. The weight of particles of this kind varies according to the difference of the ramenta; if these are thick, the particle will be heavy; if thin or small, it will be light: but of this difference we shall say more hereafter.

With respect to the origin of the oil particles, it follows, 1. That they derive their origin from saline ramenta, or from their mutual friction and accumulation on the surface of the bullæ of subtle matter. 2. Oil is formed when common salt is broken up, either by distillation or crystallization, or when its component parts are agitated upon each other in any other manner. 3. *When these ramenta are submitted to a distilling heat, they are converted into oil;* to which the subtle matter is supplied by the fire, and an abundance of ramenta by the distilled salt: whereupon the oil passes over from the retort. 4. *Oil may in the same way be produced in the sea,* where the salts are broken by mutual shocks, and their ramenta dispersed

over the subtle matter that is diffused between the interstices of the water; whence oil is found even in the salt sea. 5. The particles of oil may likewise be generated in the soil, since there is a sort of distillation of the subtler salts in the earth. 6. *Oil is also produced in the animal body,* by the subtle distillation of the particles of salt. Thus we see that true oils arise from common salt, when recent and new; and why they are especially formed in retorts.

§ 3. *The origin of urinous or volatile alkaline salt.*

We think that the particles of volatile urinous salt are merely saline ramenta, (Fig. 3;) for according to our theory it follows, that, 1. If the ramenta join the subtle matter, they stick to it closely, and are converted into oil, nor can they be separated, unless by fire, or by lapse of time. 2. But if these ramenta be adjoined to particles of water, they cannot be fixed at all, but the connection is of the very loosest kind. 3. The result is the same when they are joined to particles of air. 4. Hence if a ramentum be applied to a particle of water, it glides and moves about on the surface without being attached; and the least motion of the water suffices to separate it; precisely like the saline particles, which being of the same substance, cannot at all attach themselves to the water particles. 5. When these ramenta strike the olfactory sense, a fetid and urinous odour is perceived; because the figures are triangular, sharp, and irregular. The same is the case, if they are brought to the nose by particles of the air. 6. But if they are attached on the surface of a volume of subtle matter, and so converted into oil, from which they cannot be separated, they then have no such odour. 7. Hence old oil turns rancid, and emits a very fetid smell; and in the same way all kinds of fat, for after fat has putrified, certain particles of a urinous nature enter into its composition. Thus oil and volatile urinous salt are not different from each other, except that in the former the ramenta adhere to the surfaces of fiery volumes, and are removed from thence with difficulty; but in the latter they adhere to particles of water, from which they can be loosened by the slightest motion,

and strike whatever bodies they encounter with their irregular points.

§ 4. *The adhesion of oil to salts.*

Granting the theoretical description of the particle of oil, viz., as consisting of ramenta on the surface, it follows, 1. That the hard matter of the fourth kind may be naturally applied to matter of the same kind; that is to say, the ramenta may be applied to salts. 2. Oils may be applied, and will adhere, to all salts whatever: because the surface of the oil consists of ramenta of hard matter of the fourth kind, and the diameter of its particles is equal to that of the water particles; so that the oil may be applied and fitted to the saline surface, and will adhere to it more closely than water, which is of the hard matter of the sixth kind. 3. If, therefore, oils be applied to particles of common salt, or to alkaline, nitrous, or acid particles, &c., they cannot be again removed unless by fire; hence the origin of the various kinds of fat. 4. Water and oil may also be combined by means of salts. 5. And salt may be converted into salt of another sort; see our Theory of Alkaline and Essential Salts.

§ 5. *The fluidity of oil.*

Since the particles of oil are round, and almost of the same dimensions as those of water, it follows that oil has the same character as water; in that it is moveable, maintains the natural position, is transposed from one position to another by fire and cold, exhibits the same trembling undulations and phenomena of motion as water; and in short, whatever can be said of the fluidity of water, may also be predicated of the fluidity of oil.

§ 6. *The decomposition and change of oil by distillation.*

If oil be distilled, it is plain from the theory of its composition, that, 1. Its particles are gently decomposed in the retort. 2. When the decomposition takes place, the large ramenta are separated from the small. 3. The small ramenta come over first, but are transferred to new volumes of subtle

matter; a thin oil, or peculiar spirit, therefore necessarily first passes over. 4. Afterwards the larger ramenta come over, but these likewise are transferred to other volumes of subtle matter. 5. Lastly, the grossest ramenta of all either come over, or remain behind with their subtle matter; whence we have dense and heavy oil. Thus by distillation, the oil particles are decomposed, and the light are separated from the heavy. 6. If the oil be distilled a second time, it divides into still smaller ramenta, which also come over; their subtle matter being supplied from the fire. 7. Some ramenta are united to each other, and in a manner agglutinated, so that they may be converted into a peculiar earthy and hard matter, which is not easily divisible by our terrestrial or sublunary fire. Therefore when oil is distilled, an insipid earthy matter remains behind; and if the distillation is repeated four or five times, this matter is at last converted into an earth, which is nothing more than the accumulation of ramenta, enclosing a few particles of very dense oil, as shewn at Plate XI., Fig. 5, where *abc* are particles of the thickest oil, beset with large ramenta. If now, by the agency of distillation and decomposition, some of the ramenta lodge in the interstices, as between *abc*, at *mno*, Fig. 5, in this case the oil particles will be bound together, and converted into a hard and earthy substance.

§ 7. *The disintegration or dissolution of oil by fire.*

It appears from the construction of oil, that its surface may be torn by the action of fire, and the force and friction occasioned thereby: for as the crust of the oil particles consists of ramenta that only adhere to the subtle matter enclosed within, so the surface is easily dissolved and broken when the ramenta are set in motion by the fire: whence it follows, 1. That when oil is exposed to the action of fire, the particles are set in motion, and are broken, partly by friction, partly by the force of heat. 2. When the subtle matter enclosed within the particles is liberated, it is dilated, and carried upwards into the air with a part of the ramenta. 3. The disintegrated ramenta are dispersed among the particles of the air. 4. The particles of oil may be dissipated by the action of fire in the same way as the par-

ticles of water; viz., by being first converted into bullæ and vapours.

And not only are oils disintegrated by fire, but they are also decomposed spontaneously in course of time. Thus, 1. When oil has been at rest for a long time, one ramentum spontaneously separates from another; the most ponderous slip down to the bottom, and the light rise to the top, until at length the crust varying in different parts breaks like a bubble. 2. The disintegrated material adheres either to particles of the same nature, or to particles of water, or without any fitness of proportion, to the air, and so occasions a peculiar putrefaction of a malignant kind.

§ 8. *Fat.*

If the oil particles adhere to the saline, that is, if the oil be applied to the walls or parietes of the salt, and the two, being of the same kind of matter, become attached together, and nothing but fire will separate them; then it follows that, 1. When oil is applied to the particles of common salt, it sticks in the cavity of the arms or branches, and cannot be easily separated: thus oil may be combined with water; which otherwise it could not be, owing to the different weight of the respective volumes of these fluids. 2. If a particle of oil be placed between two particles of salt, it adheres to each of them, and thus, by this attachment, the salt loses half its nature. 3. If an oil be applied to a saline cube, it adheres to it likewise, and thus two, three, five or more cubes may be fastened together by oily particles, and combined into various forms, respecting which we refer the reader to our Theory of Alkalis and Essential Salts. 4. If oil comes against the parietes of the acids of salt, it sticks to them likewise, and the acids immediately lose their power as a menstruum, which depends on their separate presence among the particles of water. 5. If oil be applied to the particles of nitre, it adheres to them also. 6. Hence if salts of different kinds be mixed with oils, not only are the properties of the salt destroyed, but likewise those of the oily fluid, which becomes inspissated. 7. If a given kind of salt be added in certain proportions to oils of different kinds, it changes their qualities;

thus if nitre, or acid, or cubic salt be mixed with oil, or if these be mingled with water, we shall have oil, either viscid or limpid, or tallow, wax, resin, fat, bitumen, asphaltum, naphtha, amber, petroleum, camphor, sulphur, &c. But in this sketch we pass over the structure and internal constitution of these substances, since oil and the urinous alkalis require a lengthened description; and we only mention those points that appear to elucidate the theory of sulphur, vitriol, and alum.

The various mixtures between the particles of oil, water, and different kinds of salts, give rise to fluids of various orders, as, 1. Urine, with its salt and spirit. 2. Blood, and the albumen of eggs. 3. Milk, and its coagulum. 4. Certain urinous salts, as sal ammoniac. 5. The salt of tartar. 6. The salt of hartshorn and several others, the theory of which the reader will see in a separate division. In the meantime, we shall supply the experiments for those who are curious in investigating the nature of these substances *a posteriori*.

EXPERIMENTS.

1. In the distillation of common salt, the flowers of urinous salt are found in a dry form in the neck of the retort.

Also in the roofs of houses where salt is boiled.

These flowers effervesce with acids.

Sulphur and urinous salt are found near saline springs.

Marcasites and pyrites are found near rocks of salt.

2. When urinous salt is distilled, much oil comes over.

Urinous salt is chiefly perceptible in putrified substances, as in decayed flesh, &c.

The chief part of the bodies of animals consists of urinous salt.

There is much urinous salt in the atmosphere. Hence scarcely anything putrifies without air.

Water contains much urinous salt, which is perceived when it becomes putrid.

When the rays of the sun are directed by a burning-glass upon water, the urinous odour is perceived.

Much urinous salt is found in smoke.

3. Urinous and fatty substances commix without any effervescence.

Urinous matter burns almost like oil.

Urinous spirit contains much air and fire, as may be ascertained in vacuo.

Wherever there is any urinous substance, the air-ducts are large; as in reeds, canes, the stalks of grain, &c.

The urinous smell is increased in acridity by lixivial alkalis.

4. Oil is lighter than water, and swims upon it.

Oil is light in proportion as it is limpid.

Oils are inflammable in proportion as they are subtle; as shewn in the case of spirit of wine, oil of turpentine, &c.

Ignited oils are not put out by water; but the water is thrown off by them, and crepitates like gunpowder.

Oils burn with great intensity.

When oil is distilled, water comes over first; then spirit, and then oil; then thick and fetid oil.

An earthy sediment remains at the bottom of the retort.

If the distillation be repeated, the oil is rendered lighter, and purer in colour, smell and taste.

If the distillation be frequently repeated, all the oil is converted into earth.

Old oil grows rancid, fiery, viscid, acrid, inflammable.

Oil cannot be united with water, unless by means of salts or alkalis.

Oily particles may find their way in considerable quantities into woods, stones, and metals, and remain in them.

The oil or fat in milk cannot easily be separated from the watery parts, if common salt, sugar, &c., be dissolved in the milk.

The oil or fat in milk is coagulated into the form of cheese by acids, vinegar, spirit of nitre, &c.

Beer does not ferment when salt is thrown into it.

Oil and fat in a decoction of ashes are precipitated by common salt as a gelatinous mass.

Fats are dissolved by lixivious alkalis.

A solution of resin is rendered thicker and denser by common salt.

5. When wax is distilled, it yields a fetid acid spirit, and

then an oil which as it cools coagulates into a butter; the remainder is converted into a fatty butter.

6. If resin be distilled, it yields first phlegm, then spirit, then a white oil, then a red oil, and afterwards a spirit with a salt, which salt can be crystallized.

Amber is inflammable, and has an odour between pleasant and urinous.

Amber is dissolved by spirit of wine in four or five days.

7. If fresh urine be distilled, it yields a fetid sulphurous water; if the fire be fierce, the colour changes from citron to yellow, red, brown, and black.

The residue is neither alkaline nor acid, but saline oleaginous.

When quick-lime is mixed with this residue, it grows warm and boils; and a volatile igneous spirit escapes.

If the residue be distilled, it yields an alkaline volatile spirit, then a fetid golden-coloured oil, and at last a very fetid oil.

When urine is stagnant, it becomes red, fetid, frothy, and viscid; then alkaline, and changes to calculus; it likewise acquires a fiery taste, and effervesces with acids.

If stagnant urine be distilled, it yields an alkaline volatile fluid, which is fetid, and effervesces with acids; then a volatile salt in a dry state, and then an oil.

The caput mortuum exposed to a great heat, yields blue fumes, which are very brilliant in the dark; the substance at the bottom of the retort is phosphorus.

Phosphorus is not readily soluble by water; if it be boiled, it yields something of common salt.

Fresh urine boiled with common salt becomes alkaline: after its depuration, it may be sublimed into sal ammoniac.

8. Blood does not effervesce, either with acids or alkalis.

Blood is rendered fluid by a gentle heat, but coagulated by a greater.

When blood is distilled, it yields water, and then an oily alkaline spirit, which may be resolved into phlegm, volatile salt, and yellow oil. Afterwards a white, volatile, rhomboidal salt comes over, which may be resolved into a golden-coloured oil and a volatile alkaline salt. Lastly, a thick oil with a volatile salt.

The substance at the bottom swells up and may burst the vessel; but it can be converted into a pitchy oil, and the salt at the bottom is sea-salt.

Blood is coagulated by alcohol.

Blood emits a urinous odour in the fire.

9. If the albumen of egg be distilled, it yields an insipid, perfectly pure, and inodorous water; then a golden-coloured spirit, which may be resolved by rectification into water, an alkaline volatile salt, and oil: then a volatile alkaline salt in a dry form, which may be resolved into a yellow oil and an alkaline salt as white as snow; then a golden-coloured, light, fetid, and alkaline oil, and lastly a thick, very fetid and black oil.

A spongy, insipid, and black earth remains at the bottom of the retort.

The albumen or white of egg is coagulated by fire and alcohol, but is rendered fluid by a very gentle heat.

When the white of egg putrifies, it loses the power of coagulating.

10. Milk is white and sweet.

Milk boils over the fire; it is coagulated by acids, and converted into cheese.

In a short time the oily particles rise from the milk, the water sinks down, and becomes somewhat sour; the intermediate part coagulates.

Milk unites with water; is bound up with common salt; and agrees with spirit of wine.

Milk mixed with an alkali loses its colour, and becomes red, like blood.

11. Sal ammoniac consists of one part of urine, one part of common salt, and half a part of soot.

Sal ammoniac is found in the urine of animals, in hot places, and near Mount Ætna.

Sal ammoniac does not effervesce either with acids or alkalis. It cools water down to a very low temperature. It burns with a greenish-blue flame.

Eight parts of it yield 4½ of spirit, the rest is converted into flowers: a white mass remains, which, when crystallized, yields a white salt.

If sal ammoniac be sublimed, alkaline flowers like snow

lodge in the head of the retort; the same result takes place, though the sublimation be repeated a thousand times.

Almost the whole may be sublimed.

The flowers of sal ammoniac have a fiery and acrid odour; they are very penetrating, and deliquesce in the air; the oftener the salt is mixed and sublimed, the more fiery do they become. If common salt be mixed with sal ammoniac and distilled, a fiery vapour ascends; then by increasing the fire, these alkaline flowers are obtained; they are very acrid, they evaporate on the least warmth, and, unless preserved in close vessels, they deliquesce in the air. When mixed with water, they form the spirit of sal ammoniac.

When these flowers are mixed with quick-lime, they give out a thin, fiery, and very mobile vapour.

When all the volatile part has been driven off, a salt remains at the bottom of the retort, which is common salt.

Sal ammoniac is soluble in water, and more easily when fixed alkali is added.

Sal ammoniac mixed with quick-lime supplies a very penetrating spirit.

Sal ammoniac coagulates in spirits of wine.

Sal ammoniac neutralizes acids.

When sal ammoniac is sublimed, it swells very considerably.

Sal ammoniac has the power of dissolving small portions of gold and antimony, and of precipitating certain metals.

12. Salt of tartar is found in wine casks.

It is not soluble without boiling.

When distilled, it yields a sub-acid, bitter spirit, containing one-tenth part of acid; then a thin and most penetrating oil; afterwards a strong, heavy, fetid, thick oil; and at the bottom of the retort a black and inflammable matter is left, which is converted into oil of tartar per deliquium.

Salt of tartar promotes fermentation.

It does not react, either with spirit of vitriol and acids, or with urinous salts.

If the caput mortuum be calcined, it yields a very pure alkali.

When placed in the fire, it goes through great variations of colour.

13. When horns are distilled, an insipid water comes over first; then an acrid oily alkaline spirit, which, when rectified, separates into water, salt, and oil. Then an oily, volatile, alkaline salt of a yellow and red colour; then a yellow, volatile, light, fluid oil; and lastly, a very fetid, black, and tenacious oil.

A black earth remains behind in the retort, which may be converted by fire into perfectly white, insipid ashes.

When this earth is dissolved, nothing can be distilled from it but an insipid water devoid of any saline properties; but if the decoction be evaporated, it again yields water, salt, and oil.

14. Spirit of wine is exceedingly inflammable.

In proportion as it is thick, it is ardent or burning.

In proportion as it is thin, it yields less smoke, residue, and combustion.

It yields a little oil in distillation.

When the subtlest spirit is spilled, it at once evaporates into the air.

Spirit of wine is destroyed by acids, and *vice versâ.*

Spirit of wine and spirit of nitre distilled together afford a harmless vinous liquid.

When spirit of wine and other lighter oils, as oil of turpentine, &c., are mixed with spirit of nitre, the mixture grows hot, boils, and almost half of it evaporates; while what is left is weakened. The same result takes place if they are mixed with oil of vitriol, although to a less degree.

Spirit of wine agrees in a manner with spirit of salt.

Spirit of wine is deprived of its acridity by various salts, for instance, by common salt.

Spirit of wine is coagulated by common alkaline salt.

Fixed and volatile alkalis are crystallized in some measure by spirit of wine.

Salt of urine is coagulated by rectified spirit of wine, and forms a sediment at the bottom of the vessel.

Spirit of wine precipitates a little of what has been dissolved by acids.

Quick-lime is not heated by spirit of wine, but nevertheless the spirit is absorbed.

The most highly rectified spirit of wine turns milky when mixed with water.

Spirit of wine reddens when mixed with aqua fortis.

Spirit of wine is reddened by syrup of violets.

Spirit of wine dissolves certain fatty sulphurous substances, &c., &c., &c.

APPENDIX,

CONTAINING SOME GENERAL RULES CONCERNING TRANSPARENCY, AND WHITE, RED, AND YELLOW COLOURS, TAKEN FROM OUR THEORY OF LIGHT AND RAYS.

We are about to transfer to these pages a few selections from the Theory of Light and Colours, because we wish to proceed to the consideration of metals, which can scarcely be investigated unless we have a previous knowledge of colours. As the entire Theory, which must precede the Theories of Fire, Air, and Ether, is of considerable length, we shall here mention a few general rules concerning transparency and certain colours, reserving the geometrical demonstrations on the subject for the work itself.

§ 1. *Transparency.*

Rule.—*All particles in this sublunary world, whether hard or soft, are naturally transparent.* This rule is geometrically demonstrated in the abovementioned theory, where the reader will find the dimensions of the hard particles, as well as of the elements, compared with those of the particles of light, which pass through all bodies in nature. This rule is rendered still more evident by experiments; for, 1. We see that the elements are transparent, and so also the particles of the elements. 2. We see that the ether is transparent, and that nothing hinders our vision from reaching the sun. 3. Fire and heat are evidently transparent; but with regard to flame, it will be seen elsewhere, that it loses its transparency by containing particles

of very different kinds. 4. Air is evidently transparent, so that we can see without retardation through several miles of air. 5. And water also, provided its particles are in the regular position. 6. The particles of common salt are transparent, as we see when it is in solution; for when they have been received in the interstices of water, we find that the light is transmitted through them as readily as through pure water. 7. Alkaline, acid, nitrous, vitriolic, volatile, and other particles are in the same way transparent, so long as they are arranged in a regular position amongst the water particles. 8. Metals are also transparent, as is plain from the solution of metals in chemical menstrua, and their conversion into glass. 9. Gold is transparent, as appears from its solution in aqua regia, and from its conversion into glass by the action of the burning-glass. 10. The particles of light pass through silver, when it is dissolved by acids, or converted into glass by fire, or into luna cornua by the combined action of fire and solvents. Thus the actual particles themselves are transparent, provided they are arranged in a regular order, but they lose their transparency when they lose their regular angles. 11. Light is transmitted through lead, when it is either dissolved in a menstruum, or converted into glass, into which it passes with great facility. 12. That light passes through iron and steel, is clear when they are dissolved in aqua fortis, or reduced into glass by fire. 13. Stones and earths of various kinds are convertible into glass, and perfectly pellucid in that state; in which case it is the same identical particles that are arranged in a new position. 14. The scoriæ of iron, copper, &c., if cooled rapidly, afford a very pellucid glass; but if cooled slowly, the same particles exhibit no transparency whatever. 15. Light passes through mercury, as during its evaporation, which takes place without any smoke, or the least sign of refraction or colour. 16. It follows, that not only earths and stones of various kinds, but even the hardest metals, are transparent, provided their particles are arranged in a regular position, and at equal distances. But their becoming opake, and exhibiting colours, seems to be owing to the paths of reflexion being filled up in all directions with subtle matter: which matter is compressed and dilated in different ways and degrees, according to the shape and calibre of

FIG. 1.

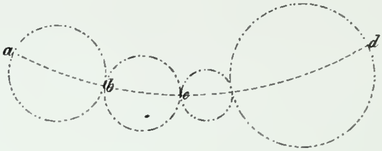


FIG. 2.

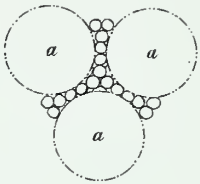


FIG. 4.

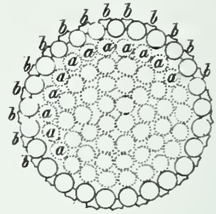


FIG. 5.

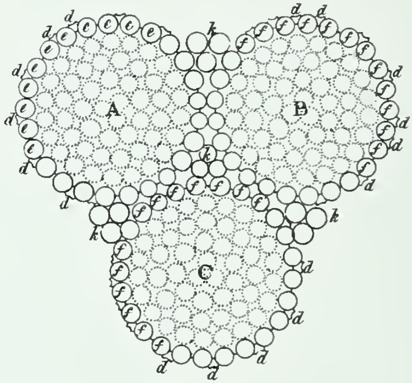


FIG. 6.

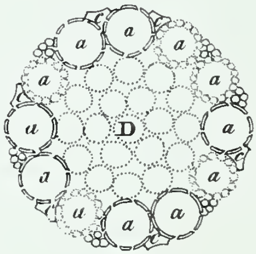


FIG. 7.

the pores that it enters; and communicates a different refraction to the rays that permeate it, whereby the light is confused, and colours of various sorts are represented.

I see that it may be objected to this view, that the particles, even though not transparent, may nevertheless be so placed as to transmit the light directly through their interstices, in which case the pellucidity may be owing to their position, and not to the transparency of each individual particle. And this view may be further confirmed by reflexion. We shall, however, show elsewhere by what arguments it is to be combatted.

§ 2. *White.*

RULE.—*If the angles of reflexion in transparent particles be confused in various directions, the colour of white is produced:* that is to say, if the particles of a body be so arranged as to be pellucid, and if afterwards the angles be confused irregularly, or in other words, if the transparent particles be mixed confusedly in different ways, we say that in this case white will be the result: this is plain,

1. *From bullæ.* For, 1. If any transparent liquid be thrown into froth or bubbles, it becomes perfectly white, although each bulla by itself is transparent, and transmits the light like water. But as the several bullæ are of different sizes, and the transmission of light is various and irregular, so we maintain that the body grows white on this account. Thus in Plate XII., Fig. 1, *abcd* are water bubbles of various sizes. Now when the light is transmitted through *d* and *c* to *b* and *a*, it will be reflected in different ways. Whether the liquid, so long as it is transparent, be yellow, or red, or blue, it loses its colour and becomes white when converted into froth. 3. So likewise, if water be impregnated with common, alkaline, acid, nitrous, or any other salt, it whitens as soon as it is converted into froth and forms particles of various sizes. 4. Wines, beer, and liquids of all kinds and colours, afford similar results. 5. And the vapours distilled from saline bodies are white, because the bullæ are of various dimensions, as is plain from the distillation of nitre, salts, &c.

2. Owing to the same cause, *a mixture of liquids of different*

kinds produces a milky whiteness. Thus, 1. If water be mixed with alkohol, we see the mixture turn milky; for the particles of alkohol, that is, of highly rectified spirit, differ from those of water, especially on the surface; whereby the transmission of light undergoes a change, because it passes through the particles in the same way as through bullæ and froth of different kinds: that is, when two such pellucid fluids are mingled in one, the transparency is converted into white, owing to the confusion of the paths of transmission. 2. So again if water be digested with oil, the mixture turns milky, because there is a difference in the reflexion of light through the round particles of oil and of water. 3. Milk is almost as white as snow, on account of the mingling of different kinds of particles, and the variation of the rays that pass through them. 4. The same thing is seen in various chemical mixtures of fluids, which also are milky: for if the particles of one fluid be like *aaa* (Plate XII., Fig. 2), and those of another like *bbb*, then, although they are both round and transparent, a white colour will arise from their commixtion, according to our rule.

3. *By the fracture of pellucid bodies.* All bodies, whether hard or not, present an appearance of whiteness, if broken while their particles are in a regular position. This is clear from the following instances: 1. If glass that is transparent be reduced to powder, the latter will be perfectly white; because the angles of reflexion, in the pellucid pieces to which the glass is reduced, are thereby confused, so that the light cannot pass straight through, but is broken by many obliquities and prisms. 2. A similar result is obtained with any kind of coloured glass, whether red, yellow, &c. 3. When lumps of ice are powdered, or rubbed down into minute pieces, they turn as white as snow. 4. The same result occurs when horn, resin, and other pellucid bodies are ground into powder. 5. If ice be studded with any great number of minute bubbles, it likewise becomes white. 6. Glass or *vitrum mariæ* becomes as white as silver when its laminæ are disturbed by fire, although it is otherwise quite pellucid. 7. Various kinds of salts are white, but when dissolved in water, they are transparent; such is the case with common salt, which is white, with vitriolic salt, salt of nitre, and lixivial alkaline salt. 8. If one part of sulphur be mixed

with three parts of salt of tartar, and vinegar be added, the mixture turns milky, and a white precipitate is formed. In a word, all pellucid substances are white when they vary the angles of reflexion: which proves that whiteness is nothing more than a commixtion of transparent particles; which are transparent so long as they preserve the natural position, but when they change this regular arrangement by fracture or otherwise, they immediately become snowy white. This is best seen in snow, for if its particles be examined, they will be found to consist of perfectly pellucid lamellæ or plates, which unite to form a transparent ice, but which become white when divided, 9. We see the same again in silver, which is transparent so long as its particles are in a regular position, as in its crystals, and in luna cornua; while in other states, this metal is white. 10. Hence according to our rule, whatever is snowy or white is naturally pellucid, and its particles individually transmit the light; so that were there an operator present who could simply alter the arrangement of the particles, any white body might at once be rendered transparent.

§ 3. *Red.*

Rule.—*If the surface of the particles be variegated by particles of a different kind, the colour of red is the result.* Thus if water, oil, or any other species of liquid be extended into bullæ, and their surface be beset with particles of two classes, in such case we say that the particle or bulla will be red. This is seen in the following instances: 1. If any salt, as common salt, or salt of nitre, be distilled, the vapours redden when the surface is variegated by acids and particles of two kinds. Thus in Plate XII., Fig. 4, we have a bulla of vapour of acid spirit, in which *aaaaa* are the water particles, and *bbbbb* the acids in the interstices of the former. Now we affirm that this bulla will be red, on account of the transmission of the rays through the two kinds of particles. 2. The same is the case with sulphurous particles, which, according to the Theory of Sulphur, are as represented in Fig. 5: in which instance the particles of oil and water are extended together into bullæ, as A, B, C, and *eeeee, ffffffff,* but in the interstices they are studded

with the acid particles *dddd;* hence if the sulphur be separated by the oil, the particles redden, because the light is transmitted through two orders of them. 3. And this is the reason why spirit of wine reddens when mixed with acids. 4. Blood and milk redden when mixed with alkalis. 5. Alkalis at last redden when calcined with a strong fire; and this, because they are agitated and swollen by the fire, and so pass into bullæ; the surfaces of which are variegated either by acids, alkalis, or some other kind of particles: but on this subject see our Theory of Alkalis, and of the Calcination of Vitriol, Lead, &c. 6. The amalgam of mercury with sulphur furnishes cinnabar; because the particles of the mercury lie concealed in the little sulphurous bullæ. Thus in Fig. 6, D is a sulphur, *aaaa* are oils and waters, and *cccc* are acids, while *bbbbb* are mercuries. Now when the sulphur is beset with acids and mercuries together, we say that in this case the light will be transmitted in various directions, and as it were crucially, and so will produce redness. This, however, will be better seen in our Theory of Sulphur and of Mercury.

§ 4. *Yellow.*

RULE.—*When white is mixed with red, yellow is engendered.* Thus, if red particles have waters, oils, or any other kind of particles in their interstices, so that the red transmission is impeded by these intermediate particles, we assert that in this case yellow will result. Whence, 1. If sulphurous particles, as ABC, Fig. 5, which otherwise are red, be alternated with other particles, as *kkk,* either of oil or water, yellow arises. In order to show this more clearly, suppose that the particles of sulphur ABC are not covered by the acid particles *ddd,* and yet have intermediate particles, as *kkkk;* then, owing to the diversity between the transparent particles, a white mass will be produced, according to § 2: but when ABC are covered by the acids *ddd,* and the intermediate particles are still there, the red will be converted into yellow. 2. So likewise, when a fixed alkali is digested with sulphur, it turns golden yellow. But these points will be more fully seen in our Theory of Light and Colours.

PART XXV.

THE THEORY OF LEAD: CONTAINING A GEOMETRICAL AND EXPERIMENTAL DEMONSTRATION OF ITS PARTICLES OR INTERNAL MECHANISM.

Metallic particles.

The order of the subject requires that we now treat of metals, so as to shew the truth of our Theory of Elements and Salts, which we have in part delivered in these *Specimens*. Up to the present time, chemists have differed greatly as to the actual substance of metals. Some hold them to be compounds of sulphur, mercury, and salt. Others omit the latter from their composition; and others, the mercury also. The result is, that nothing certain has yet been produced, on which the human mind can rest; and *a fortiori*, nothing geometrical. We shall, however, in this place, endeavour to treat the subject in the same way as we have already treated the subject of salts; that is to say, we shall give the forms, positions, motions, and other geometrical conditions of metallic particles, with a view to draw therefrom a mechanism of invisibles. For in the whole sphere of leasts there is nothing that produces varieties, but a peculiar mechanism and practical geometry. By mechanism and geometry is nature bound, in all the varied phenomena she displays, and in all the distinctive experiments with which she

endows us. Let us, however, confess that in researches of this kind, the mind of the enquirer is peculiarly liable to illusion; the imaginary may easily be mistaken for the true, and the shadow for the substance: especially as in this field the objects are purely mental, and the mind and the inner eye are the only organs of vision. Yet since we find that all things have laws, that experiments are under the empire of geometry, and that the mechanism of invisibles may rest on the basis of calculation and partake its infallibility,—since, we say, we are assured of this, we may put forth the following statements with all just confidence. All we ask is the kind attention of the reader, and his assent to whatever we adduce that carries with it the force of geometry.

According to our principles, we suppose water to consist of hard particles of the sextuple dimension; water being the sixth dimension; one of its crustal particles being the fifth, the crustal of this again, the fourth; and so on, until we arrive at the mathematical point, which is the *ens primum* of all particles whatever. From these principles it follows, 1. That saline matter weighs to aqueous in the proportion we have given in the Theory of Salts. 2. But with regard to *metals, their weight is increased by the disintegration of the particles of the third kind in the bowels of the earth;* where the particles being perfectly at rest, and deprived moreover of all soft circumambient matter, are resolved into particles of smaller size, and insinuate themselves into the pores of the larger particles; whence *by the accession of new matter and weight to the saline figures, the latter are converted into metals, &c.*

If metals be compounds of hard particles of the fourth and third orders, (as will be seen to be the case throughout in our Theory of Metals, and especially in that of mercury, which we shall shew to consist of the crustal particles of water combined with particles of the third order, previously disengaged and afterwards fixed; and, indeed, to be similar in its particles to Fig. 1, (Plate XIII.), which represents a crustal of water, but with its internal cavity and the interstices between its

FIG. 1.

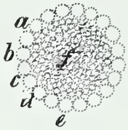


FIG. 2.

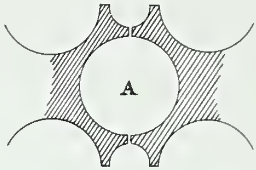


FIG. 3.

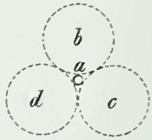


FIG. 4.

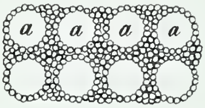


FIG. 8.

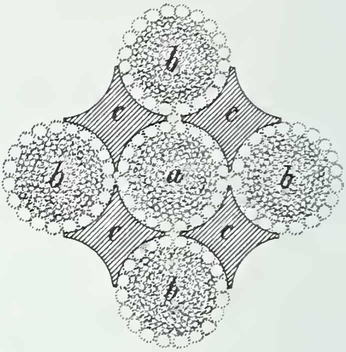


FIG. 11.

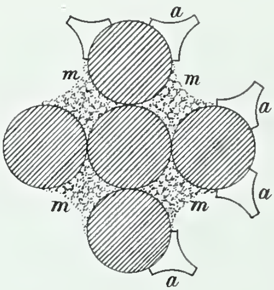


FIG. 9.

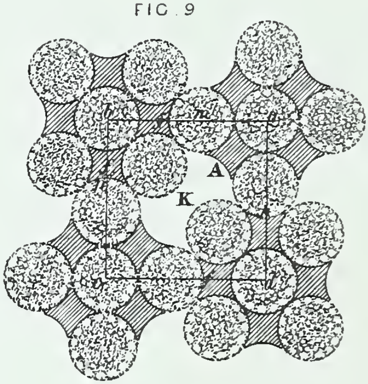
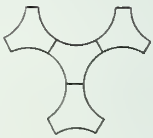


FIG. 10.



crustals, filled with the hard matter of the third order); then it will follow, that,

1. *A volume of such particles weighs to a volume of water as* $14\frac{6}{11}$ *to* 1; which is thus demonstrated. Let the weight of the hard particle of the fifth kind, *i.e.* of the crustal particle of water, = 1. If there were no cavity in the crustals composing this particle of the fifth order, (which, however, on our principles, there is,) then one such particle would weigh twice as much, or = 2, because the space of the cavity is equal to the space of the crustals. If likewise the interstices between the particles of the fourth kind, which are on the surface, be filled with matter of the third kind, the weight of that crustal particle should, according to the previous calculation, = 3. But if the cavity itself be filled with matter of the third kind, as in Fig. 1, (since the space of the cavity is equal to the crustal space,) then it will weigh to the crustal particle of water as 6 to 1. But all the crustal particles remain entire, and the hard particles of the third kind can only fill up the interstices and the internal cavity; hence such a particle must weigh to the crustal particle of water as 5 to 1. Now we say that such a particle is mercurial, and that a volume of such particles will weigh to an equal volume of water as $14\frac{6}{11}$ to 1. And this is demonstrated as follows. Let the weight of one of the crustals of water, agreeably to the calculation, = 5. If the ambient crust of water consisted of such particles, it would weigh to a common particle of water as 5 to 1. Now the internal cavity of the water particle occupies the same space as the crust; hence if this cavity be filled with the same particles, the full particle will weigh to the particle of water as 10 to 1. But as we wish to ascertain the entire weight of the volume, the interstices that there are between the water particles must be filled with particles of the same (the third) kind. Now since the interstices in the natural position of water are to the full space as 5 to 11, hence $11 : 5 :: 10 : 4\frac{6}{11}$, which if added to 10, gives $14\frac{6}{11}$ as the weight of a volume of such particles; which is exactly equal to the weight of mercury.

2. *Globules, equal in size to water particles, are formed out of this matter.* This is plain from the circumstance, that of all the compositions in nature, the most common is from salts and

water; the waters being evidently enclosed in the arms and concavities of the salts: and even after their conversion into stony masses, and various species of material substance, we still observe in the latter round pores and cells in every part; and we think that if the aforesaid mercurial substance were placed therein, a particle of the same dimensions as water would result. Thus if the stony or saline composition in the bowels of the earth be as represented in Fig. 2, (Plate XIII.), where the concave part A corresponds to the dimension of water; and if by chance the water particles be disintegrated, and so form lesser particles, and their place be occupied by others, then in this case particles will be formed of the same dimension as the cavity A, or as the water particle. And thus a globule may arise from mercurial matter that shall be of the same magnitude as the small aqueous space, according to the proposition.

3. *A particle the size of the water particle, but consisting of mercurial matter, will weigh to the water particle as* 10 *to* 1. This we have already demonstrated above in section 1.

4. *If this same particle, which is equal in size to the water particle, has hard matter of the third kind in its interstices, it will weigh to the particle of water as* $14\frac{41}{88}$ *to* 1. This is demonstrated as follows. Let the former particle weigh to the water particle as 10 to 1. If the interstices be filled with the same matter, (the space of which interstices is to the space of the particles in the fixed triangular pyramidal position as 131 to 352); and if they have no particles of the fourth kind in them, but only particles of the third, then the above particle will weigh to the water particle as 12 to 1; hence $352 : 131 :: 12 : 4\frac{41}{88}$; and if this be added to 10, we obtain $14\frac{41}{88}$ as the weight of our particle. Such metallic particle, therefore, is to a water particle as $14\frac{1}{2}$ to 1 nearly.

5. *Saline matter, or salts of different kinds, may be filled with hard particles of the third order in the same way as the above-mentioned crustal of water;* which is thus demonstrated. If, agreeably to our principles, the dimension of the particles be decuple, then it follows that the next smaller compound may enter into the interstices of the larger compound, so as to fill not only them, but the cavity itself. Thus in Fig. 3, (Plate XIII.), *bcd* are particles of the fourth kind, and as the diameter of

a particle of the third kind is only $\frac{1}{10}$ of their diameter, so *a*, or the third kind, may enter into the interstice between the fourth, *b, c, d,* which interstice is $\frac{1}{7}$ part of *b* or *c*; and hence particles of the third kind may enter into those of the fifth, and those of the second into the fourth, and those of the fourth into the sixth, &c.; whence a saline compound may be penetrated by a solution of the particles of the third kind; in the same way as water, by a solution of those of the fourth kind, &c.

6. *The weight of the metallic matter is to that of the saline as* $5\frac{1}{4}$ *to* 1; which is thus demonstrated. Let the saline matter be composed according to the theory in the foregoing pages, that is, let *aaa*, Fig. 4, (Plate XIII.), be the crustal particles of water, or of the fifth kind, and let the intermediate particles be of the fourth kind: if now, matter of the third kind be intermingled with the particles of the fourth kind, not only are their intervals filled up, but likewise the internal cavities, *aaa*, of the fifth kind, as has just been demonstrated from the decuple dimension of the diameters. Now let the space of the crustals $=1$, the space of the internal cavity$=1$; the full spaces are to the interstices in the fixed quadrilateral pyramidal position as 3 to 1; consequently as 2 to $\frac{2}{3}$; whence the space occupied by the fourth kind$=1\frac{2}{3}$, and its double quantity$=3\frac{1}{3}$. Thus the ratio of the interstices occupied by the matter of the third kind may be obtained; that is, $352 : 131 :: 3\frac{1}{3} : 1\frac{127}{528}$. If the cavity be filled with matter of the third kind, it would weigh$=3$, as demonstrated above; therefore we must add $3+1\frac{127}{528}+1$ together; for $3=$the weight of the cavity when filled; $1\frac{127}{528}=$the other interstices filled up with matter of the third kind; and $1=$the weight of the salt; all which collectively afford us $5\frac{127}{528}$; so that the weight of the metallic matter is to that of the saline nearly as $5\frac{1}{4}$ to 1, or as 21 to 4.

7. *A metallic triangle or acid weighs to a particle of water as* 13 *to* 9. *Demonstration:* If the metallic matter be to the saline as 21 to 4, and a saline acid be to a water as $2\frac{1}{2}$ to 9, then the metallic acid is to the water as 13 to 9 nearly.

8. *A metallic cube weighs to a particle of water as* 26 *to* 9. This is a consequence of the preceding, as the weight of the cube is double that of the triangle.

9. *A particle of metallic oil weighs to a particle of water as*

5 *to* 1 *nearly.* For a particle of oil is nearly of the same weight as one of water; but if the ramenta consist of metallic matter, the weight will be as 5 to 1; or more exactly, as the metallic weight to the saline.

10. *Saline matters, as acids, fixed alkalis,* and other substanccs which are more or less composed of the matter of common salt, *adhere to the metallic globules;* as may be supposed from the harmony of composition subsisting between the particles. Thus the mercurial globule is of the fifth dimension; and if a number of these globules form a larger globule as big as a water particle, and the interstices be filled up with matter of the third dimension, as has been mentioned above, we see that the above resemblance or harmony consists in the metallic compound being formed of matter of the fifth and third dimensions; and the saline of the fifth and fourth: but the difference is, that the globule of the fifth kind in the metal is five times heavier than the globule of the fifth kind in the salt. Nevertheless, owing to the agreement in composition between them, that is, owing to their both being of the fifth dimension, it follows of necessity, that they may be united together; which the reader will see at once, if he only considers the mechanism.

We have wished to explain briefly the nature of the particles in the metals, and the result is, that, 1. There are mercurial globules, weighing to a particle of water as 14 to 1 nearly. 2. There are metallic salts, weighing to other salts as 21 to 4. And as the composition of the particles is from hard particles of different kinds, and especially from salts in the bosom of the earth, so we are not aware whether on these principles any figures can be generated besides those that we have now shewn to be produced naturally and mechanically, and which only differ from those previously treated of in the accession to them of subtler matter, and in their larger combination.

THE THEORY OF LEAD.

We have chosen to commence with the theory of this metal, because it appears to consist of very simple particles, and because none but metallic particles are found in it; on which

account it is well calculated to give us an idea of the genuine composition of metals, according to our principles.

§ 1. *Description of the particles of lead.*

The particle of lead consists of metallic globules and cubes which have combined to form one body. Its composition is to the last degree natural, and indeed arises spontaneously from the commixtion and fixation of metallic globules and cubes. For when cubes and globules are mixed together and set in motion, if the mechanism of their fixation and composition is compared with the mechanism of their respective figures, it will be seen that the only possible result is, to form a particle consisting of six metallic cubes and thirteen metallic globules; because each cube is of 90°, and thus six such cubes will exactly occupy the space round one globule; and one globule will find room exactly between any two cubes. Hence six cubes and twelve globules are necessarily ranged and combined round one metallic globule. Their mutual fixation, and the close conjunction between them, follows from the similarity of their component matter; for the metallic cubes are of the same matter as the metallic globules, and therefore mutual conjunction springs from mutual contact. Motion, therefore, being given among these particles, that is, amongst the cubes and globules, we necessarily obtain a larger particle, similar to this that we consider to be the particle of lead. It follows, that, 1. The particle of lead is like Fig. 8 (Plate XIII.), which however only shows a section of the particle. 2. In the middle at *a* is the metallic globule described in the Preface. 3. The metallic cubes are disposed on all sides, as at *cccc*. 4. They again enclose other metallic globules, *bbbb*. 5. Hence, by the aforesaid composition, *there are six metallic cubes and thirteen metallic globules in a particle of lead.* 6. By the mechanism of the particles, if the metallic globule be of the same size as the aqueous, and the metallic cube be of the same size as the saline, then *six cubes will exactly enclose one globule, or accurately fit its surface:* for four such cubes surround the globule, because the arc of each cube is 90°, and four of these arcs constitute a circle. Hence there are twelve spaces between six such cubes grouped

round a globule, and with the space occupied by the enclosed globule, there are thirteen: so that in one particle of lead there are thirteen globules and six cubes. 7. Hence, by its composition, *the particle of lead is nearly round;* such being the result when one globe is surrounded by twelve others, and the intermediate cubes do no more than distinguish the globules. 8. *The position of these particles is the fixed quadrilateral pyramidal,* which, in fact, the position of the six cubes requires. But if the reader wishes to know the ground of the matter, and the mode whereby these particles are enabled to combine into this form, he will find it demonstrated in detail in our Theory of the Origin of Metals. *In the first place,* the salt originating from the water in the bosom of the earth, being dissolved and then crystallized, and then dissolved and crystallized again, by the very mechanism of round and cubic bodies, will necessarily combine into the precise figure already described. *In the second place,* it is to be observed, that the globules are united with the metallic cubes in the same manner as polished marbles; for where the particles are of the same character and size, one body attaches itself to another by simple contact; not so water and salts, which are separated by the least motion, on account of the difference of their particles. When, therefore, the convex surfaces of the round particles are applied to the concave surfaces of the cubes, they must combine mechanically into one particle, consisting of thirteen globules and six cubes. Suppose that these cubes and globules are mixed and shaken together, in this case one particle will be mechanically attached to another by the affinity and geometry of their figures; attached, that is to say, so far as the motion permits. Of course in the end the particles will be conjoined in the manner described above. After they have thus combined, it would seem to be no longer possible to separate them by motion. And if a particle or two should join a composition of the kind, with a view to attach themselves to any portion thereof, as this figure, which tends towards sphericity, and is amazingly compact, would be injured by their accession, so they will be plucked away by the first motion that arises, and the figure of the compound particle will in this manner be preserved.

§ 2. *The composition of the particles of lead in mass.*

A PRIORI.

When these particles are aggregated in a mass, one will necessarily apply itself to another in agreement with the mechanism of the figure of each. Hence, 1. *The convex portion of one will be applied to the concave portion of another;* that is to say, one globe to one cube, as in Fig 9 (Plate XIII.), where *a* fits *b* at *m;* or *b* fits *c* at *n;* the cube of the one being conjoined with the globe of the other. 2. *Since, on our principles, the matter in the globes is the same as that in the cubes, so the two will adhere together like polished surfaces of marble, nor be released from this condition by any means short of spiral rotation* [convolutionis]. 3. And hence *one particle of lead is so attached to another, that it cannot be torn away, although it may be rolled off from it;* in short, there is a tenacious cohesion between the particles. Whence, by our theory of the conjunction of particles, lead is not brittle, but tough and ductile.

As to the position of these particles, it is to be observed, that, 1. *This second composition of these particles is also in the fixed quadrilateral pyramidal position;* that is, they are so arranged, that the horizontal plane is as represented in Fig. 9, where all the particles are joined together in a right line, and form squares in every direction. 2. *The vertical plane is similar to this horizontal,* as shewn in Part VIII. of these *Principles,* § 7, on the Different Positions of Round Particles. 3. *There is an aperture or hiatus in the middle,* as shewn at K. 4. *The space of this aperture is to the space of a single particle of lead as* 1 *to* 3*;* as has been demonstrated in the same Part. 5. *Thus there is room in this space for* $4\frac{1}{3}$ *particles of the same size as water.* For as there are thirteen globules in an entire particle of lead, and as the intermediate space equals one third of it, so this space $= 4\frac{1}{3}$. Thus the vacant space between the particles of lead is equal to the space of $4\frac{1}{3}$ particles of water. 1. In the fixed quadrilateral pyramidal position, the full spaces are to the interstices as 3 to 1. 2. The particles of lead are in this position; see Fig. 9, where the side *amb* consists of two diameters of a water particle, and of one diameter of a cube. 3. Let the

semidiameter of one metallic globule, or of one water $=5$; then the side of four semidiameters will $=20$; and since the diameter of the cube is to the semidiameter of the water as 4 to 5, so *ab* will $=24$, whilst the semidiameter of the water $=5$. 4. The spaces of regular particles are as the cubes of their sides, and hence the interstices of such particles are to the interstices of water in the same pyramidal position, as their cubes; that is, as $24 \times 24 \times 24$ to $5 \times 5 \times 5$, or as 13824 to 125, or as 110 to 1 nearly. 5. As in this fixed quadrilateral pyramidal position the ratio of the interstices is to the full space of the particles as 1 to 3, the spaces of the particles of lead will therefore be as $110 \times 3 = 330$. 6. As, by our theory, there are thirteen globules in this space, each globule will weigh $\frac{330}{13} = 25\frac{5}{13}$. 7. If now 110 be divided by $25\frac{5}{13}$, it will be seen how many particles of the same size can be placed in the same space; namely, $4\frac{1}{3}$; so that the interstices of the particles of lead correspond to the space of $4\frac{1}{3}$ particles of water.

It follows from the conjunction of the particles, 1. That *this composition*, in which the convexity of one particle is applied to the concavity of another, *is particularly tenacious.* The particles may be released from it by a slight torsion or twist, or a gentle spiral rotation; and to this the ductility and tenacity of lead are owing. 2. If the intermediate spaces be enclosed by particles of another order, for instance, either sulphurous or aqueous, the ductility will be destroyed, because the convolution of the particles will thereby be hindered.

A POSTERIORI.

1. Lead is a ductile metal, and consists of particles whose cohesion is strong: a sign that the particles of lead are joined by simple contact, namely, the cubes with the globes; and that a slight motion suffices to separate them.

2. Lead melts below a red heat; that is to say, one particle easily recedes from another by the action of fire, which proves the above view. And this indicates, that there are peculiar cavities between the particles where the fire can enter, and perform its work of separation more easily than between the particles of any other metal.

3. Lead is readily dissolved by certain acids, and by distilled vinegar; which indicates that the particles cohere by simple contact, and that there are interstices which the water can enter in company with the acids, and so separate the metallic particles from each other. From this also we may perhaps conjecture, that these spaces are large enough to receive the water particles into them.

§ 3. *The weight of lead in mass.*

A PRIORI.

Lead weighs to water as $11\frac{1}{2}$ *to* 1: as is thus demonstrated: 1. The weight of the metallic cube to the weight of the particle of water is as 26 to 9, according to the demonstration in the Preface. 2. The metallic globule weighs to the particle of water as 14 to 1. 3. The intermediate space between the particles of lead is sufficient to contain $4\frac{1}{3}$ water particles. 4. Hence, *firstly*, the particle of lead, consisting of thirteen globules and six cubes, weighs to the particle of water as $26 \times 6 + 117 \times 14 = 1794$. *Secondly*. If we substract the weight of the water particles in the same space, they are equal, in the first number or composition of 13, to the number of the metallic globules. Then, as there is an intermediate space that is occupied by nothing but subtle matter, yet is large enough to contain $4\frac{1}{3}$ particles of the size of those of water, so in the space just calculated there might be $13 + 4\frac{1}{3} = 17\frac{1}{3}$ water particles; which, if multiplied by 9, will give 156. *Thirdly*. On comparing the specific gravities of the particles of lead and of water, they are as 1794 to 156, or as $11\frac{1}{2}$ to 1 nearly.

A POSTERIORI.

1. Lead is a very heavy metal, because it consists of metallic particles.

Lead is heavier than tin, iron, or silver.

2. Lead weighs to water as $11\frac{1}{2}$ to 1, according to the experience of many chemists; in all which particulars we may perceive that our theory agrees with the facts of the case.

§ 4. *The solution of lead.*

A PRIORI.

The combination of particles affords us the means of judging of their dissolution by menstrua. We have already observed that, 1. The particles of lead do not cohere closely, although tenaciously. 2. The spaces of the particles are sufficiently large to allow a particle or a particle and a half of water to enter into each. 3. Hence, *to dissolve the particles, not only acids are required, but waters also.* 4. *The particles of pure acid,* as of nitre and vitriol, may indeed be forced into those ample interstices, but they *will be fully concealed in the pores;* for if the interstices are so large that there is room for a particle or a particle and a half of water, an entire acid may enter, but its power of impulsion and separation will be lost in the cavity. 5. Hence, *if acid spirit be diluted with water, the water particles will not only be forced into the aperture, but they will render it narrower by their presence, and so enable the acid to exercise its powers.* 6. If the acid particle M, in Fig. 10, (Plate XIII.), enters into the cavity A (Fig. 9), which is larger than the acid particle, it must necessarily be entirely concealed therein; and thus lose its power as a menstruum. But if a particle of water also enters, the space will be immediately narrowed, and the acid particle will be enabled to exercise its power by the assistance of the water. 7. It follows that *lead is soluble in distilled vinegar,* in which there is a preponderance of water particles, and a larger kind of acid particles, more easily than if the acid be very strong. 8. *Any aqua regia, if furnished with saline particles, acts upon lead;* but not so the subtler acids. 9. *Water greatly assists the solution of the particles.* 10. The acid exerts its power chiefly at the joinings of the particles, as at *ffff,* in Fig. 9, where the disjunction of the particles takes place. 10. A cold ebullition is produced in a solution of leaden particles, owing to enclosed particles of soft subtle matter, which when their meshes are broken, escape into the water, and rise to the surface: or perhaps it is likewise owing to the occupation of the spaces in the water, and the expulsion of the subtle matter therefrom.

As to the *solution,* it follows by the same mechanism that, 11. *It is diaphanous, clear, and brilliant,* because the particles are arranged in the water in the same way as those of common salt, and the light passes through them. 12. *When once dissolved, they may be kept divided by the slightest contact with acids;* because their cohesion is not so close as to prevent them from being loosened by any slight impulse from the acids and waters. 13. *The solution of lead at first is sweet,* owing to the rotundity of the particles; see Fig. 8, (Plate XIII.), where the metallic globules *bbbb* stand out at some distance from their cubes, whereby a round form is given to the particles; so that, as the particle contains twelve globules on its surface, it is nearly round, and imparts a certain sweet taste to the papillæ of the tongue. 14. *Saline acids readily fit the metallic globules,* and are not separated therefrom by any means short of fire; which inseparability is owing to the correspondence between the two sets of bodies: see the Preface on metallic particles, n. 10. 15. Hence, *soon after solution, the sweetness is lost, and the lead globules are found to have a pungent and austere character.* In Fig. 11, the acids of the vinegar or other spirit fit the convexity of the metallic globules, as at *aaaa,* so as to offend the papillæ of the tongue by a peculiar austerity; but on these subjects see the Theory of Taste. 16. Hence also *the acidity is lost both in spirit of nitre and in distilled vinegar;* and pure water remains instead of the spirit. 17. Acids adhere better to the particles of lead than to those of any other metal, because they are in part stored away or hidden at *mmmm,* and thus are not torn away so easily as if they occupied a space on the risings *aaa.*

A POSTERIORI.

1. Lead is very soluble in distilled vinegar.

Likewise in the vapours of common vinegar.

Any strong acid spirit, like aqua fortis, for example, does not dissolve lead so well as when the same spirit is diluted with pure water.

In like manner it does not readily dissolve the calx of lead. These circumstances indicate that the interstices between the

particles of lead are so ample that the acid particles may enter them and be masked therein; and consequently they exert no power, unless water particles be added to them. The water particles occupy the same places, and make the pores narrower, so that the acid can operate upon them.

8. Aqua regia dissolves lead, but not so easily as gold; because this kind of acid has particles of common salt intermingled in it, which, being large, invade the pores, and assist the solution.

10. A peculiar cold ebullition takes place in the solution of the particles of lead.

11. The solution of lead in vinegar is limpid, and sometimes milky. The solution of lead in aqua fortis is limpid and diaphanous: a sign that the globules and cubes in the particle of lead are arranged in the quadrilateral pyramidal and direct position, which produces pellucidity; inasmuch as the light is nowhere broken by the obliquity of any acid particle or prism.

13. The solution of lead at first is sweet; which indicates that the particles of lead are roundish, and that parts stand out from the globules only of the particle, and not from the cubes; hence, as the several round projections of the twelve superficial globules in each particle press upon the papillæ of the tongue, the taste of sweetness will inevitably be produced.

15. But subsequently an austere taste is perceived in the solution of lead; which is a sign that the acids adhere to, and are conjoined with, the particles of lead, and that certain prominent points project from those surfaces, which in other respects are round. This is rendered sensible in the quality of austerity, or in a mixed taste between sweet and bitter.

16. The acidity of the menstruum is lost in the solution of lead.

When lead is dissolved by distilled vinegar, dilute spirit of nitre, &c., and then precipitated, no acidity is perceptible in the remaining liquid; which indicates that the particles of the acid are fitted to those of the lead, and by adhering to their surfaces, are separated from the water, whereby the acidity is lost.

Solutions of lead are not changed by acids.

Solutions of lead are changed by other salts; which also confirms the above view.

§ 5. *The volume and weight of the solution of lead.*

A PRIORI.

When a mass of lead is dissolved in distilled vinegar, or weak nitrous spirit, then it follows, by the composition of the particles, that, 1. *The volume of vinegar is at first increased by a space equal to the whole bulk of the lead.* Thus if the volume of vinegar$=a$, and the mass of lead$=b$, the first increase of bulk will$=a+b$. 2. *But as soon as the mass is dissolved, the space of the volume in the solution will be diminished to* $a+\frac{13b}{17\frac{1}{3}}$; which is thus demonstrated. As the particle of lead consists of thirteen metallic particles, all of which are of the same magnitude as waters, and as, by our calculation, the intermediate or interior space is equal in bulk to $4\frac{1}{3}$ aqueous particles, so the space of the lead will$=13+4\frac{1}{3}=17\frac{1}{3}$. As soon, however, as the lead is dissolved, these interior spaces are lost, being occupied by the water; whereby the volume of the solution is diminished from $a+b$ to $\frac{17\frac{1}{3}a+13b}{17\frac{1}{3}}$.

The weight, however, is increased by the solution of the particles; and it is plain that *the weight of the volume is greater after than before the solution:* for as the bulk of the volume and of the lead is diminished after the solution, the specific weight of the volume will necessarily be augmented, since the same quantity of matter remains. This is calculated as follows: Let the space of the volume of vinegar$=a$, the space of the lead$=b$, the weight of the volume of vinegar$=m$, the weight of the mass of lead$=n$. Before the ratio of the weights is ascertained, the volume of the vinegar must be regarded as$=$to its own weight, with that of the mass of lead contained in it: that is to say, as$=a+b$. Now to obtain the weight of the volume, which is equal to the space of each body, let $a : b :: m : \frac{mb}{a}$. The weight of the whole volume$=m+n$. But the volume is diminished when the solution takes place, and hence; according to the foregoing demonstration, it is$=\frac{17\frac{1}{3}a+13b}{17\frac{1}{3}}$. The weight of this

volume augments in proportion to its diminution in space. It may be obtained by proportion; thus, $\frac{17\frac{1}{3}a+13b}{17\frac{1}{3}} : a+b :: m+n : \frac{17\frac{1}{3}\times\overline{m+n}\times\overline{a+b}}{17\frac{1}{3}a+13b}$, which is equal to the weight of the diminished volume. And if it be compared with the weight of the vinegar, it is $\frac{mb}{a} :: \frac{17\frac{1}{3}\times\overline{m+n}\times\overline{a+b}}{17\frac{1}{3}a+13b}$.

A POSTERIORI.

1. The volume of the menstruum is increased by the lead, by as much space as the mass of lead occupies.

2. But after the solution, the volume is somewhat diminished; which is a sign that the whole space is occupied by the lead while it is entire; but that, when it is dissolved, the interior spaces between its particles are occupied by waters.

3. It has not yet been ascertained by experiment how much the solution diminishes in bulk, or increases in weight.

§ 6. *The crystallization of lead by its mixture with salts, and its evaporation.*

A PRIORI.

If the lead particles crystallize or unite in a regular manner with the particles of common salt, the union takes place in the vertical position of the particles. See Fig. 12 (Plate XIV.), where *efgh* are particles of lead, and *abcd* particles of common salt; in which case we say, that the two sets of particles, naturally, and by the dimensions of their figures, may combine according to Fig. 12, and the particles of lead be arranged in the cubic or vertical position, having an intermediate cavity between them; this takes place by the mutual application of the particles through the medium of water. 2. The saline particles *abcd* not only join at the sides, but also in the vertical parts *efgh*. 3. *The horizontal plane in these crystals is equal to the vertical,* exactly according to the vertical position of the particles. 4. *In these crystals, constituting the salino-plumbous*

FIG. 12.

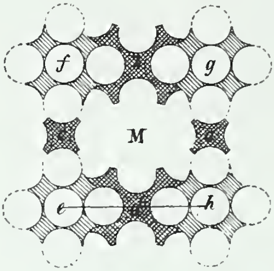


FIG. 13.

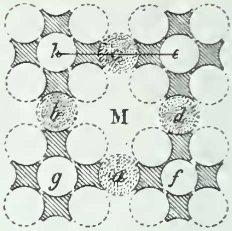


FIG. 14.

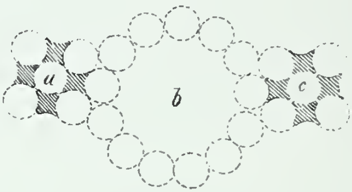
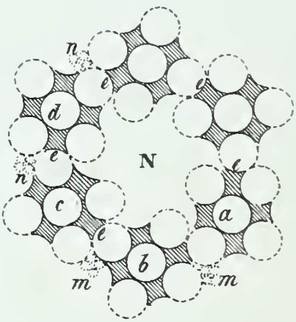


FIG. 16.

FIG. 15.



mass, the foramen M *extends upwards, downwards, and sidewards, parallel to the planes.* 5. *If the crystallization be regular, the mass is pellucid, and exactly cubic in form.* 6. *It is also lamellar, and may be divided both perpendicularly and horizontally.* If, however, the lead and the common salt crystallize irregularly together, owing either to a deficient or overabundant supply of water and salts, then, 1. The particles are no longer ranged in cubic forms, but the metals are united to the salts here and there in various places. 2. The crystallization is not lamellar, but resembles an amorphous powder. 3. The foramina do not pass through the mass in parallels, but unequally, or particles of water are enclosed in them. 4. *The crystals are not transparent, but rather present the appearance of a white powder, owing to the confusion of their particles*; according to our Theory of White. And hence we cannot perceive any regular dimension either of positions, forms, or weights. It is likewise to be observed, that if the water be very scanty, and the salt too abundant, the crystals will in this case be confused by reason of the deficiency of the water particles, whereby they should have been transferred into the proper places.

The particles of lead may likewise crystallize spontaneously from the menstruum in which they are dissolved. This is owing to defect of acids, which adhere to the metallic globules, as already pointed out; so that the mere accession of water suffices to combine them and throw them down to the bottom. But we said that the saline matter attaches itself to the metallic; and hence, 1. *The acids adhere to the surfaces of the metallic globules.* 2. *So also the saline cubes.* 3. *And the particles of common salt,* because they consist of the same matter. 4. *Therefore, when salt is thrown into a solution of lead, the particles are conjoined, and the solution first turns milky, then thickens, and at last is precipitated in the form of a white powder.*

The crystallization of lead by evaporation. When the water fails, owing to evaporation, that is to say, when the interstices become destitute of waters, then, 1. The particles are conjoined by the simple application of their sides. 2. If there be water to assist the crystallization, and to make it regular, the particles are combined together agreeably to the mechanism of their figure, namely, in the fixed quadrilateral pyramidal position,

which is the position of the particles in the mass itself. 3. In this quadrilateral pyramidal position, the particles may combine cubically, and grow forth into spires and branches. 4. On the contrary, when the water is deficient, they combine irregularly, and form a peculiar powder without any regular shape.

The difference of the crystallization of lead by evaporation and by salts, appears to consist in the following particulars; 1. The acids and salts that lie in the vinegar, adhere to the metallic parietes, and enter into the composition of the crystals. 2. Subtle fiery matter exists in the interstices of the lead, and is there compressed in proportion to the size of the pores and the subtlety of the particles in the lead; respecting which see our Theory of Fire. 3. And since the matter is compressed within, and the particles mutually cohere, it is not surprising that they may be sundered by fire, and exploded like gunpowder or fulminating gold, as will be more fully seen in the Theory of Fire. But if the lead be precipitated by salts, the latter join the particles of lead, and form a new and peculiar compound.

A POSTERIORI.

1. Lead is precipitated from its solution by common salt.

When common salt is added to a solution of lead, the mixture turns milky, and a white powder is precipitated.

We can seldom observe any regular crystallization taking place by means of salts. All these points indicate that the particles of salt combine with those of lead; and in a confused manner; whereby an irregular figure and a white colour are produced. This irregularity arises from the acids that adhere to surfaces of the globules of lead.

Lead in solution is likewise precipitated by lixivial alkalis.

But in a less degree by urinous alkalis.

Calx of lead is precipitated more regularly by means of salts, as will be seen presently.

2. Lead is precipitated from its solution spontaneously.

But still better by adding common water, which is a sign that the particles of acid are absorbed by the lead, or combined with its particles: whence it follows, that a precipitation and spontaneous crystallization take place from defect of acids.

Lead, with the assistance of water, sometimes crystallizes regularly, and germinates into spires and branches.

3. It likewise crystallizes in consequence of evaporation.

Crystallization of lead by salts differs from the crystallization by evaporation. In the former, the salts unite to the lead particles; in the latter, only the acids.

4. It is found that lead precipitated by evaporation is explosive in the same manner as fulminating gold.

But in our *Principles* we shall treat more in detail of this mechanism of crystallization. The whole matter is too long to insert in the present *Specimens*.

§ 7. *The weight of the crystals of lead.*

A PRIORI.

A mass of lead that is crystallized in the most regular manner by means of the particles of common salt, weighs to its bulk of water as 5 *to* 1 *nearly;* as is thus demonstrated. In Plate XIV., Fig. 12, let the position of the particles be vertical or cubical. The side of the cube *eh* is equal to six semidiameters of an aqueous globule, with one diameter of a saline cube. Consequently, $eh = 6\frac{4}{5}$. We ascertain how many water globules that cubic space requires, whose side $= 6\frac{4}{5}$ semidiameters, by cubing the number $3\frac{2}{5} = 39\frac{38}{125}$, nearly $= 39\frac{1}{3}$. Therefore $39\frac{1}{3}$ water particles would occupy the space of the cube comprised within the sides *adh*. We say, however, that in that space there are not more than thirteen metallic globules, six metallic cubes, and three saline cubes. With respect to the weight, a metallic globe weighs to a water as 14 to 1; a metallic cube to a water as 26 to 9, or as $2\frac{8}{9}$ to 1; and a saline cube to a water as $\frac{5}{9}$ to 1. We shall thus have $14 \times 13 + 2\frac{8}{9} \times 6 + \frac{5}{9} \times 3 = 201$, and since $39\frac{1}{3}$ water particles may be contained in the same space, we may obtain the ratio of the weights of the volume of water and of the mass of the crystals of lead $= 39\frac{1}{3}$ to 201, or as 1 to $5\frac{13}{118}$; so that the weight of the volume of water $= 1$, and that of the regular crystals $= 5\frac{13}{118}$, or very nearly $5\frac{1}{9}$.

If there be a perceptible difference in the weight, it arises from one of the following causes. 1. From some metallic, sul-

phurous, or water particles; for the weight is increased when the cavity M is filled with any heterogeneous particles. 2. When *abcd* are metallic instead of saline cubes; or when the entire saline particles occupy the place of the cubes, as at *bd*, Fig. 12; though in this latter case the increase of weight will be but trifling. 3. When *abcd*, instead of cubes, are oily or sulphurous particles; of which we shall speak in § 8.

If the particles of lead are combined by the intervention of sulphurs or oils, then, 1. The mass may be divided into lamellæ. 2. It may be converted into genuine particles of lead by the action of fire, which takes place by sundering the intermediate particles from those of the lead. 3. This mass is not ductile, but brittle. 4. It may be impregnated with heterogeneous particles. 5. This crystallization weighs to its bulk of water as 5 to 1. 6. It is dissolved with great difficulty by any menstruum. 7. And when dissolved, the volume of the solution is at first augmented, but afterwards it subsides into a smaller space, and crystallizes again spontaneously.

A POSTERIORI.

Owing to the above causes, viz., the adhesion of acids, salts, &c., disturbing the position, it is difficult to obtain any regular crystallization of lead, excepting the crystallization of its calx, of which we shall treat presently. We may, therefore, suppose that the regular crystallization takes place, if not by means of precipitation, at least by conjunction in the earth, as in mineral lead, or lead ore, which has all the appearance of perfectly regular crystallization. See § 8.

§ 8. *The saline and sulphurous ore of lead.*

A PRIORI.

Lead ore seems to be similar to crystals in this respect, that the lead particles in it are bound up with saline or stony cubes, or with sulphurous particles. In the former case it follows from the description lately given, that, 1. *The position of the particles is cubical or vertical.* 2. *The internal construction of the*

particles is similar to that in the crystals. 3. *The vertical and horizontal planes in the vein are alike.* 4. *They can be divided and scaled off from every side both cubically and in layers.* 5. *It weighs to a corresponding volume of water as* 5 *to* 1.

The particles of lead may be crystallized by globules in the same manner as by cubes. This kind of crystallization differs from that described above in nothing but weight. For the convex surface of the globules may be applied to the concavity of the metallic cubes reciprocally as before, as shewn in Fig. 13, Plate XIV. 1. *The particles of lead are mutually united together by the intervention of globules at the places abcd;* and this, reciprocally, in the same manner as the former application of the saline cubes to the metallic globules. 2. *Lead may be crystallized in the vertical position,* as before. 3. *And also in layers;* which may be scaled off parallel to the sides, as before. 4. *There are cavities or foramina that permeate the mass parallel to the sides,* as before. 5. *When this crystallization is regular, it is pellucid also.* 6. *If irregular, it is of a dark colour,* owing to the irregular emptiness of the spaces. 7. *If the matter in the interstices* M *be heterogeneous, it resembles silver.*

The weight of such a mass or ore is to the weight of its bulk of water as 9 *to* 1; which is thus demonstrated. 1. The side *hce* in Fig. 13 is equal to four semidiameters of a globe, together with two intermediate cubes, which $=1\frac{3}{5}$; so that the whole side *hce* $=5\frac{3}{5}$. 2. The cube of $5\frac{3}{5}$ is $175\frac{77}{125}$. 3. If this be divided by 8, the number of waters in the same space may be obtained; $=22$ nearly; so that a cube of this kind occupies the space of 22 globules of water. 4. But only one particle of lead and three globules are contained in the same space; their weight being $14\times 13+2\frac{8}{9}\times 6+1\times 3=202\frac{1}{3}$. 5. By comparing this number with 22, we obtain the proportion of the weights of water and of this ore, viz., as 1 to $9\frac{1}{5}$, nearly.

But these substances may differ in weight; 1. If the cavity M be full of some other matter. 2. If the globules be saline, oily, or metallic. 3. If, instead of globules, there be occasional cubes or salts; and these, either metallic or saline.

But lead ore or crystals may be much lighter, if instead of the globules *abcd,* sulphurous bullæ be interposed, as in Fig. 14: where the particles of lead *ac* are united with the intermediate

bulla of sulphur *b;* and so constitute lamellar cubes in the manner before described and demonstrated. It follows, however, that, 1. *Such a vein weighs to a volume of water particles as* $2\frac{1}{2}$ *to* 1 *nearly,* &c.

A POSTERIORI.

1. Lead ore occasionally exhibits a globose appearance.

Sometimes it appears radiated.

But generally it is tessulated and of a cubic form; which indicates that the particles of lead are combined by cubes, or stony or saline particles, into a regular form; as above demonstrated.

Wherever the ore is broken, the fracture is cubical; a sign that the position of the particles is vertical, and that the combination of them takes place by sulphurs and salts.

Lead ore will scale off in layers, both horizontally and vertically; which indicates the same as before; it will scale off, that is to say, in the direction, and according to the planes, in which the particles are conjoined with the above-mentioned figures.

Lead ore contains much bituminous earth. This indicates the presence of cubes and sulphurs connecting the particles, and which are separated from the metal by the action of fire, and afterwards dispersed: whereby, when the heterogeneous matters are thrown out, the particles of lead combine reciprocally.

The colour of the lead ore is grey; which shews that the position of the particles is vertical; and that there are large foramina between them, that absorb the light.

If the particles be disturbed, the colour of lead ore, and especially of metallic lead, is white, like that of silver.

2. Lead ore weighs less than metallic lead.

Lead ore stands in different ratios of weight to water, in proportion as it contains more or less earth, stone, salt, sulphur, &c.

Lead ore sometimes weighs to water as 8 to 1, which nearly agrees with our calculation.

Sometimes it weighs to water as 5 to 1, which likewise coincides with our calculation; and moreover indicates that the par-

ticles of lead are distinct and divided from those of another kind, which render their position more open, and diminish their weight; but of this crystallization we shall treat more fully in our *Principles* than we possibly can in these *Specimens*.

§ 9. *The Colour, and the variation of colour, exhibited by the particles of lead.*

A PRIORI.

It is shewn in the Theory of White, that transparent particles of different kinds become white, whenever they lose their regularity and transparency; in other words, that white is produced, whenever transparent particles of two different kinds are commingled. Hence, 1. *If particles of lead be mixed in an irregular manner with waters, whiteness, and a colour exactly like white lead, are produced.* The reason is, because there are two kinds of transparent particles, viz., leads and waters; and as they differ in size and component matter, the light transmitted through a particle of one kind must necessarily pass through that of the other kind in a different manner; whereby whiteness is produced. 2. *If particles of another kind be mixed with those of the lead, whiteness is caused in the same way;* as when the particles of vinegar, or any other solvent fluid, are attached to the surfaces of the lead, whereby whiteness is occasioned, owing to the irregular refraction of the pellucid particles. 3. *If particles of salt be attached to the leaden surfaces,* so that the lead is reduced to powder, and the rays of light in consequence are confused and broken, *white is the necessary result.* 4. *If waters likewise be interspersed, red is produced,* viz., by the irregular pellucidity of the three regular bodies. 5. The particles of lead occupy a very regular position, both in the ore, in masses of lead, and in its crystals. 6. *But if the position be disturbed,* so as to place the internal cavities in an irregular arrangement, *a dark and black hue appears;* respecting which see our Theory of Black. 7. *If the interstices or cavities be filled with heterogeneous matter, a snowy whiteness arises.* 8. *If the planes only be disturbed,* without any heterogeneous matter, *a silvery colour is induced.*

A POSTERIORI.

1. When lead is dissolved in vinegar, the solution at first turns milky.

2. If the lead be precipitated by salt, the solution thickens, and a white powder falls down; indicating an irregular position and commixtion of the transparent particles.

The same result takes place when the lead is precipitated by lixivial alkalis.

Or by evaporation.

3. If lead be exposed to the air in the vapour of vinegar, it contracts white spots, and some red ones, like the rust of iron; which is a proof that waters, acids, and particles of lead, are all commixed and confounded.

4. The colour of lead is grey.

But if the position of its particles be disturbed by hammering, &c., its colour appears silvery.

If the position of its particles be disturbed by melting, the same silvery colour appears; which indicates irregularity of position among these metallic particles.

For if saline and aqueous particles be admixed with metallic, the colour is milky and not shining; but if there be many metallic particles, or none other, then the colour is metallic or silvery. Light passes through metallic particles, furnished as they are with very subtle pores, otherwise than through saline particles, and with greater compression. But on this subject, see our Theory of Colours.

§ 10. *The fluidity of the particles of lead in water.*

A PRIORI.

It is plain from the mechanism of the particles of lead, that they tend to spontaneous conjunction and precipitation, unless prevented by water particles. To prevent this conjunction, it is necessary that, 1. *The number of the particles of water should be to those of the lead as* 29 *to* 1 *nearly;* which is thus demonstrated. The particle of lead contains 13 globules, and if surrounded by waters, the number of the latter = 18; for six waters

may adhere to the cubes, and the remainder to the superficial globules. To prevent the particles of lead from uniting, the water must quite surround them, and so hinder them from coming in contact with each other at any point. This is the case when the particle of lead is beset by eighteen waters, whilst others fill up the intermediate spaces. The number for these spaces is thus obtained; as $8 : 3 :: 13+18 : 11\frac{5}{8}$; whence the number of waters to the leads is as 29 to 1 nearly. 2. Or if we wish to obtain the weight, *the water will weigh to the lead as* 1 *to* $6\frac{25}{29}$, *before any combination can commence;* which is thus demonstrated. There are twenty-nine waters and one lead. The latter weighs to a single particle of water as $199\frac{1}{3}$ to 1. If this $199\frac{1}{3}$ be divided by 29, the quotient $6\frac{25}{29}$ will be the weight of the lead. 3. *Or,* which comes to the same thing, *if the weight of the solution be to the weight of water as* $5\frac{3}{7}$ *to* 1, *then the leads may float about without any combination occurring between them;* which is thus demonstrated. The weight of the volume of water = the weight $29+13=42$. And the weight of the solution $=29+199\frac{1}{3}=228\frac{1}{3}$. Whence $42 : 228 :: 1 : 5\frac{3}{7}$.

A POSTERIORI.

Distilled vinegar or any other acid spirit dissolves only a certain quantity of lead. But the exact quantity has not yet been ascertained by experiment.

§ 11. *The liquefaction of lead by fire.*

A PRIORI.

The texture of the particles will enable us to form a conclusion as to the manner of their separation by fire. In the preceding pages we have observed, that the particles of lead adhere together by the simple contact of their globules and cubes, and have very ample interstices between them, equal to $4\frac{1}{3}$ particles of water. Hence, 1. As these ample interstices are replete with subtle fiery matter, and as their sides cohere together, so *they are easily separated by fire.* 2. *This separation*

takes place quietly, and below a red heat. 3. *If there be any heterogeneous matter in the interstices,* such as particles of sulphur, oil, &c., *it is driven off,* and the mass is thereby purified. 4. *Lead melted by fire is fluid like water, because the particles tend to assume a round shape.* 5. Lead cannot be separated, either by our sublunary fire, or by any menstrua, into smaller particles than those already described. 7. *Could the metallic globules be separated from the cubes, a volume of the former would weigh to a volume of water as* 14 *to* 1 *nearly;* which is the same proportion as between mercury and water. 8. And they would form a liquid of which certain metals are composed, provided salts be added; respecting which see our Theory of the Origin of the Metals.

A POSTERIORI.

1. Lead is easily separated by fire.

Lead is melted by fire, below a red heat.

Melted lead is fluid like water; all which circumstances shew, that the particles are united but slightly, and by contact only; and that they are of a rounded form.

Lead melts more rapidly when oil or tallow is added to it.

2. Lead is purified by fire.

5. Some chemists hold, that lead can be divided into still smaller particles by the action of menstrua, and indeed into a fluid, or a peculiar mercury; which ought to be verified by experiment.

§ 12. *The calcination of lead.*

A PRIORI.

Lead is calcined when it is melted, and stirred for one, two, or three hours. Whence it follows, 1. That the subtle fiery matter forces itself more and more into the interstices: 2. And separates the particles from each other. 3. Hence *a peculiar intumescence arises mechanically between the particles.* 4. And as one particle coheres with another by its sides, we may easily conceive that at length by agitation and fire, the particles of lead will pass into bullæ like those in Plate XIV., Fig. 15,

where *abcd*, &c., are particles of lead joined together by their globules and cubes at *eeee;* the subtle fiery matter being inclosed in the internal cavity N. 5. This takes place mechanically by stirring and the action of fire, and by the spontaneous cohesion of the particles. 6. *Thus the particles of lead are transformed into calx;* the change of nature being apparently due to the simple change of position in the particles.

If the melted mass is stirred about for a longer period, then, 1. Its particles are distended into still larger bullæ. 2. And into new particles of rounded shape. 3. Thus the very nature of the calx may be altered by dint of agitation and fire. 4. We shewed in the Theory of Oil, that *certain oily or bituminous particles are created by fire;* these particles are like Fig. 16; their surface consists of saline ramenta, but their internal cavity contains a volume of fiery matter. The ramenta easily follow the fiery current, and accompany it into the metallic interstices: they are formed into oily particles in the same way as in the retorts; viz., by surrounding some little fiery volume. Hence if the matter of lead be agitated for a long time, and distended into fresh bullæ, or into calx, we need not be surprised if the saline ramenta be brought thither, and ranged round the little fiery volumes so as to form new oil particles; of which we have treated in the Theory of Oils. 5. As therefore fresh particles are created in the interstices of the leaden bullæ by means of the fire and ramenta, it follows, *firstly*, that new particles come into the interstices of the larger particles, that is, *nnmm*, into the interstices of the bulla, Fig. 15; so that on the surface, between the particles of lead, there are new bituminous particles, that take possession of the same surface, together with the rest. *Secondly*. The weight of the lead is thereby augmented; which is owing to the calcination and fire.

A POSTERIORI.

1. Fire has a power of distending and separating particles.

It likewise has the power of forming the separated particles into bullæ; for instance, the particles of water.

2. If lead be melted and stirred about, it is changed into a white calx and ceruse. All these facts indicate, that the par-

ticles of lead, when separated, are fluid like water, and are extended into bullæ in the same way as water. And when the mass cools, they adhere in that position by mutual cohesion; whereby the calx is produced.

3. The calx of lead is heavy and brittle.

It differs in colour, and appears as if it differed in substance, from lead.

4. When lead is calcined, its weight is increased by the fire only.

§ 13. *The variation of colour in the calx of lead.*

A PRIORI.

When lead is calcined for half an hour, or an hour, it follows that, 1. All the particles cannot pass at once into the form of bullæ; or if they did, one bulla would be larger than another, and many particles would be intermediate between them. 2. Hence, according to our Theory of White, the confusion of the translucent particles, or the mingling of large and small, gives rise to whiteness. 3. But afterwards, when the bullæ are made equal by calcination, two kinds of particles are ranged round the surface, viz., the leaden and the bituminous; whereby the surface is variegated, and changed more and more from white to yellow, verging towards red. For by the Theory of White, if the surface of a bulla consists of two kinds of particles, as in Plate XV., Fig. 17, (where large particles are represented at *abcd*, with smaller ones contained in their interstices,) red is inevitably produced, and the mass itself reddens equally with the individual particles. *So when the calcination of the lead is continued for a long time, the mass becomes intensely red, owing to the sprinkling of small particles in the interstices of the larger*, as *mmmm* between the bituminous particles *abc*. 4. But if the same or other particles be likewise found in the interstices of the bullæ, a yellow colour is produced thereby; respecting which, see the Theory of Yellow. By the continued action of the fire, therefore, the calx will necessarily change from white to red, that is, from ceruse or white lead, to minium or red lead, and by the change it will gain in weight.

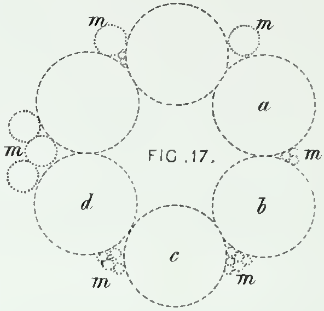


FIG .17.

FIG .18.

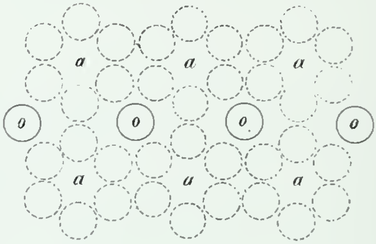


FIG .19.

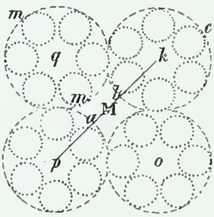
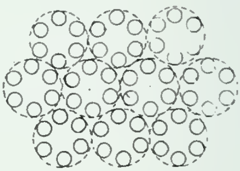


FIG .20.



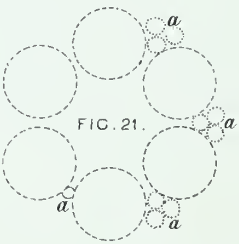


FIG .21.

FIG .22.

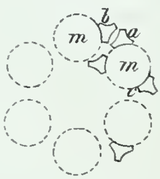
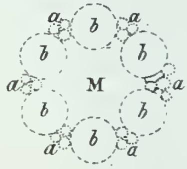


FIG 23.



A POSTERIORI.

1. When lead is melted and stirred about, it is converted into calx and ceruse.

Calx and ceruse are white. Lead may be brought into this condition by stirring about for one hour.

2. If the calx be stirred longer than this, it loses its whiteness, and passes through various colours into red. This change takes place in four or five hours. The red calx constitutes minium.

3. If it be stirred about for a long time, it also increases in weight. All these results are signs that the particles of lead are extended into bullæ in the same way as water particles into vapours. These experiments indicate moreover that new particles are created by the fire, (as oils in the retort,) which being transferred to the same surface of the bulla, and ranged around it, vary the light, that is to say, the transmission of the light through the bulla; whence the yellow and red colours.

In like manner, if three parts of minium and one part of crystals be melted together over the fire, the mixture goes through different colours, according as it is held more or less in fusion.

3. The scoriæ of lead, or litharge, swell up like the froth of water, which shews an aptitude in the particles of lead to be distended by the fire, and to keep, and cool, in this condition owing to their mutual contact.

The scoriæ of lead are of various colours, grey, silvery, yellow, red; which shows that the lead is converted into bullæ of different sizes, which are beset by particles of different kinds.

§ 14. *The dilatation of the calx of lead.*

A PRIORI.

It is abundantly evident that the particles of lead are raised up by the action of fire and stirring, and that thereby the pores in the calcined mass are rendered larger, and consequently that the latter becomes lighter than a corresponding mass of metallic lead, in which the particles lie closer together. But the degree

of dilatation caused by the fire, is difficult to ascertain from the mechanism of the particles. The power exerted by the fire in dilating the particles, depends upon the strength of the fire; for an intense fire has a strong action, but a small fire, or a lesser degree of heat, has a feeble action. The fiery bullæ, therefore, must be but little distended by a small fire, in comparison with what they are by a large one. When water passes into vapours or bullæ, we see it sometimes distended greatly, and sometimes but little; nor do we observe that all the vapours are equal in size and degree. The case is similar when the particles of lead are agitated by fire and set in motion. But if we consider the mechanism of the subject, we shall find that, 1. All the particles cannot be converted into bullæ at once, but only a part; though at last, if the calcining action be continued, they will all be converted into bullæ. 2. Hence it seems probable, that the globules or diameters of the bullæ are three times as large as the diameters of the particles of lead. Thus in Fig. 18, (Plate XV.), *aaaaaa* are globules or bullæ of calx, or particles of lead converted into bullæ: whilst the intermediate ones *oooo* are the unchanged particles of metallic lead. 3. If now each kind of particles be in motion, and likewise in the natural position, and only a part be converted into bullæ, whilst the remainder occupy the intervals between them, it will follow mechanically, that the smaller particles *oooo,* or those of the lead, exactly fill the interstices of the bullæ *aaaa,* if the motion be continued; whence the larger are in the same proportion as the interstices are to the globules. 4. From what has been said above, it follows, that *the diameter of the leaden bullæ or calx, to the diameter of the particle of lead, is as* 3 *to* 1. For if the ratio of the particles is as the ratio of the interstices; and if the diameter of the bulla is equal to *mm* or *bc,* (Fig. 19), then we say, that the bullæ of lead are dilated just so much, that the lead particle may have room in the interstice M; whereby the motion may be continued, and the proper ratio of dimension between the particles be attained, according to the ratio of their motion. If the diameter of the aforesaid bulla $bc = 1$, then according to the calculation of the spaces in the Theory of Water, $ab = \frac{2}{5}$; so that the proportion of *ab* to *bc* is as 2 to 5, or as 1 to $2\frac{1}{2}$. But the particles must at all events be capable of motion, and hence

they come in contact with each other at no point whatever, but on the contrary are to some small extent mutually separated, as is always the case with particles in the fluid position: thus *k* is a little way from *o*, *o* from *p*, *p* from *q*, and so on; whereby the space in M becomes still larger, and the diameter of the lead particles to that of the bulla or calx, is as 1 to 3.

If, by the agency of fire and calcination, the particles are dilated into bullæ, and their diameters trebled, that is, if the diameter of *k* be three times as large as the diameter of M, then, 1. *Twelve particles of lead may exist jointly in the surface of one bulla.* 2. *And this, in the fixed quadrilateral pyramidal position,* according to the combination of the cubes and globules in the particles of lead. 3. *The internal space or cavity of a bulla is equal to the space of a particle of lead. Demonstration:* If the diameter of the bulla = 3, the diameter of the cavity will = 1, which is the diameter of a single particle of lead. 4. But the interstice M in the fixed quadrilateral pyramidal position, (which the bullæ assume when the mass cools,) is to the space of the entire bullæ as 1 to 3. See the Treatise on the Different Positions of Round Particles.

§ 15. *The weight of the calx of lead.*

A PRIORI.

Ceruse, or lead calcined to whiteness, weighs to metallic lead as $8\frac{5}{8}$ *to* $11\frac{1}{2}$, *or as* 39 *to* 52; which is thus demonstrated. Fig. 19 represents the bullæ of calx with intermediate particles of lead. When they are fluxed by the fire, let the position be the natural one; but when not in a fluid state, let the position be the fixed quadrilateral pyramidal. If there be twelve particles of lead on the surface of a bulla of the calx, with room in the internal cavity for one particle more, in this case the number will be thirteen. If the position be the fixed quadrilateral pyramidal, the full spaces will be to the empty as 3 to 1, that is $3:1::13:4\frac{1}{3}$, therefore, $13+4\frac{1}{3}=17\frac{1}{3}$, will give the weight of the mass of lead. But if the particles are reduced into bullæ with intermediate particles of lead in M, Fig. 19, the substance at once becomes lighter; for, *Firstly.* One particle

of lead is absent for every cavity that is wanting. *Secondly.* As the number of squares, M, is equal to the number of particles, there is only one particle instead of the $4\frac{1}{3}$ which there might be; in short, $3\frac{1}{3}$ particles are to be deducted. As then $1+3\frac{1}{3}=4\frac{1}{3}$ is taken away from the mass of lead, or $17\frac{1}{3}-4\frac{1}{3}=13$, so the ratio of the weight of lead to that of ceruse is as $17\frac{1}{3}$ to 13, or as 52 to 39.

For we think that *ceruse* consists of particles of lead expanded into bullæ, as in Fig. 19, with certain intermediate particles of lead in the interstices M; whence, according to our theory, a white colour is produced by the mingling of two kinds of particles.

Minium, or lead calcined to redness, weighs to metallic lead as $8\frac{1}{3}$ to $11\frac{1}{2}$, nearly; which is thus demonstrated. We before said that the particles or calx become red when there is no particle of lead remaining in the interstices of, or rather in the intervals between, the bullæ, but all of them are on the surfaces; and when small bituminous particles, formed by the fire, are mingled among the larger particles; whereby the rays of light are refracted in various directions, and red is produced: see the Theory of Red. After this prolonged calcination, there are no longer any interstitial particles of lead remaining, but only bullæ, as delineated in Fig. 19; with the newly-created intermediate bituminous particles. If the whole mass of lead be $17\frac{1}{3}$, and if it gain one-ninth in weight by the medium of the fire, according to the experiments of Boyle, then the entire mass will weigh 19 nearly. But as the internal cavity is empty, one particle is removed; and then as the interstices are likewise empty, $4\frac{1}{3}$ more are removed; or $1+4\frac{1}{3}=5\frac{1}{3}$: thus $19-5\frac{1}{3}=13\frac{2}{3}$. The ratio of the weights of lead and minium, therefore, is as 57 to 41, or as $11\frac{1}{2}$ to $8\frac{16}{57}$.

But if there are particles of lead in the interstices of these bullæ, the colour will be yellow instead of red.

A POSTERIORI.

1. When lead is calcined, its weight is increased; four ounces being augmented to four ounces and thirteen grains.

2. An ounce of lead subjected to the flame of spirit of wine, yields an ounce and six grains.

3. The specific gravity, however, relatively to water, is diminished; thus this calx weighs to water as 9 to 1 nearly, according to our calculation.

4. The weight of the lead also becomes less than it was before; as we discover when we again reduce the calx to metallic lead.

§ 16. *The reduction of calx into lead.*

A PRIORI.

When ceruse or minium is melted, it is reduced to metallic lead; as might be inferred from the mechanism of its particles. For if lead is converted into bullæ by calcination, it follows that, 1. These bullæ of lead calx are resolved by the action of fire. 2. *And when resolved and rendered fluid by the fire, they relapse into a mass of metallic lead.* 3. If minium be treated in this way, something remains of the bituminous particles, and alters the character of the metallic lead. 4. But even these particles are driven off by the action of the fire; whereby the lead is as much diminished as it had been previously increased in weight.

A POSTERIORI.

1. Ceruse and minium may revive into lead, but with a diminished weight.

2. When litharge is exposed to the fire, and well stirred, it is converted into minium; but if melted again, it relapses into lead; which is a sign that the particles of lead had only passed into bullæ, and changed their position, and may be reduced to their former position by the action of fire.

§ 17. *The reduction of lead into glass.*

A PRIORI.

The facility with which lead undergoes vitrifaction, is plain from the very composition of its particles, which cohere to each other when even slightly applied together; whence they are capable of passing into the form of bullæ such as exist in glass;

respecting which see the Theory of Glass. In the meantime our view is, that in glass the merely superficial or bullular particles are mutually compressed by each other into dodecahedrons, and are so bound up thereby, that it is utterly impossible to separate them.

A POSTERIORI.

1. Lead is easily vitrified.

§ 18. *Theorems and observations respecting ceruse and minium.*

A PRIORI.

I. *The solution of the calx by menstrua.* That the calx of lead is soluble in vinegar and water, is evident from the mechanism of its particles: upon which, owing to the looseness or largeness of the interstices, and the smallness of the acids, the latter cannot act without waters; by which, therefore, they require to be assisted. Hence, 1. The strongest acid does not act on the calx so well as acid mixed with water. 2. Compound salts act more powerfully on the calx than very simple salts, and the acids of the second and third kinds more powerfully than those of the first. 3. The particles of the calx are divided by menstrua into bullæ, that is to say, into this second composition. 4. And as the bullæ are separated, the subtle fiery matter inclosed within them issues coldly forth.

EXPERIMENTS.

1. Ceruse and minium are soluble in vinegar and water.

2. During the act of solution effervescence takes place, but unattended with heat.

3. The calx of lead is also soluble in oils, as in oil of turpentine, though this requires the action of heat.

II. *The fluidity of the calx in water. When calx of lead is dissolved by menstrua, its particles will flow among the waters, until the number of the former becomes to that of the latter as* 1 *to* 87 *nearly.* If the quantity of water be great, the particles

will not combine unless they be quite at rest; but the conjunction begins when the ratio of the particles is as 1 to 87; as is demonstrated thus. As a particle of lead consists of thirteen metallic globules, and a bulla of calx of twelve, inclosing a peculiar cavity, so the space of one particle of calx = the space of 169 waters. Thus, $13 \times 13 = 169$. To fill the intervals between these bullæ, $63\frac{3}{8}$ particles of water are required, as obtained by this proportion; viz., $8 : 3 :: 169 : 63\frac{3}{8}$. But since the particles or bullæ of the calx have also interstices on their surface, which if not already filled with bituminous particles, will afford room for twenty-four water particles; hence $63\frac{3}{8} + 24 = 87\frac{3}{8}$, which number renders the calx fluid, and impedes combination so long as the volume of solution is in motion. Otherwise a much greater number of waters is required for the separation of the particles of the calx.

III. *The beginning of crystallization.* If the proportion of waters to particles of calx be less than 87 to 1, then, 1. One particle will combine with another. 2. This conjunction begins on the very surface of the water. 3. *It appears as a pellicle, just as in nitre.* This necessarily takes place, since, owing to defect of waters, one particle is applied to another, and they may be conjoined by the intervention of globules and cubes. 4. *If there be water enough, the leaden bullæ will combine in a regular manner; the process being assisted by the water,* and the whole depending on the mechanism of the particles. If, however, there be but little water, the combination will be confused.

IV. *The crystallization of the calx of lead.* The crystallization follows mechanically from the figure of the particles. 1. *They combine exactly in the same manner as nitres,* viz., in the triangular position. 2. *The base of the crystal is triangular,* as in Fig 20, Plate XV., where three particles include a space. 3. The upper particles are placed over the triangular interstices of the lower. 4. Hence *the regular crystals of calx are laminated or lamellar.* 5. *And the calx itself is a hexagonal,* and in part a pentagonal, *crystal.* 6. *The crystals tend to an apex with an inclination or slope of* 60°, in which they end. 7. *If water be present,* to range *the particles* mechanically into crystals, they *may become pellucid.* 8. Owing to the similarity of the crystallization in the two cases, the weight of these crystals

may be calculated in the same manner as that of the particles of nitre.

V. *The adhesion of heterogeneous particles to those of the calx.* It seems that a particle of calx of lead may have attached to it, 1. The round bituminous particles formed by the fire, and for which there is room in the interstices on the surface, as at *aaaa* in Fig. 21, where they lie compactly enough among the cubes of the lead. 2. Water particles may also lodge in the same interstices, and beset the surface jointly with the leads, but they adhere more slightly than oils. 3. The number of water particles in any interstice cannot exceed four. 4. *All kinds of salts may be applied to the particles of the calx of lead,* just as to lead itself; as already shewn. Hence, *firstly,* saline acids as well as metallic acids may be so applied: but if the acids occupy a place on the surface, they will, when motion happens, necessarily be torn from it, and occupy a more inward position in the interstices. *Secondly.* The particles of common salt and of some lixivial alkalis will fit and apply to those of the calx of lead equally as will the particles of the lead itself. *Thirdly.* Oils and waters may be mutually attached to each other in the interstices by the intervention of acids and salts. 5. *In fact it is clear, that particles of different kinds may be affixed to the calx of lead;* although it would occupy too much space were we to detail the mechanism of the subject.

VI. *Sugar of Saturn.* If the particles of the calx be separated and reciprocally disjoined, it follows that, 1. Each particle will have a sweet and saccharine taste, because it is in a manner round, and rolls, therefore, upon the papillæ of the tongue. 2. If the interstices are beset with oils and waters, the surface will be still smoother and more polished. 3. And the acids themselves will retire and be fully concealed in the same interstices. Hence we think that the particle of sugar of lead is like Fig. 23, Plate XV., where M is a particle of calx; *bbbbbb* particles of lead; and *aaaaaa,* waters with oils and acids. 4. So when this particle is distilled, it will necessarily first yield water or phlegm, and afterwards oil or spirit; the bulla remaining all the time with acid particles interspersed, and being capable of reduction to lead by the agency of fire.

The reason why the acid and other salts cannot be separated

from the particles of the calx, is, that no particle of salt can be separated unless by the assistance of motion. Thus, if Fig. 22 be a bulla of calx, with acids attached in the interstices of the particles of lead, as in *acb*, and if the particles *m* and *m* do not move, then of necessity *acb* will be incapable of separation until *m* and *m* are loosened from the bullular surface, and move in conjunction with the other particles; as happens in the fire. Hence as the particle represented in Fig. 22 is not loosened by the heat or fire of distillation, so the adhering acids cannot possibly be separated from the parietes. 4. Owing to the same cause, when vinegar is mixed with a solution of calx of lead, its acidity is destroyed, and a peculiar sweetness usurps its place: and when sugar of lead is distilled, a phlegm comes over without acidity; the acid having been left behind. The same result occurs when the calx is dissolved in even the strongest acid spirit of nitre. 5. But if the crystal be liquefied by fire, and one particle separated from another, so that each follows its proper motion, then the acid that is jointly therein will be separated from the globules.

VII. *The magistery of Saturn.* The particles of calx of lead may be precipitated by either common salt or lixivial salt, as is abundantly plain from the foregoing observations. Thus, 1. All salts are capable of application to, and conjunction with, the metallic globules, the respective particles of the two substances fitting to each like two pieces of polished marble. 2. And two globules may be combined and united by one particle of salt. 3. In like manner the particles of the calx may be joined together by lixivial and saline particles, thereby assuming the consistence of milk, and falling to the bottom: where it forms a precipitate, which is the magistery of Saturn. 4. When this precipitate is melted over the fire, it is reduced back again, as is commonly the case with all kinds of calx.

EXPERIMENTS.

1. When calx of lead is dissolved in a menstruum, its acidity is destroyed.

Aqua fortis with minium forms a sweet and saccharine menstruum.

When the solution is distilled, no acid water comes over.

Minium dissolved in vinegar and evaporated to the consistence of a pulp, yields sugar of lead.

And when calx of lead is dissolved in vinegar, distilled in a sand bath for three days, and evaporated, it in like manner yields sugar of lead.

Sugar of lead is sweet, like other sugar.

2. Sugar of lead is soluble in oil of turpentine, and the solution is red.

3. When salt of Saturn is distilled, phlegm comes over first, then a peculiar spirit: (the latter when rectified yields an ardent spirit, of an austere taste, which is inflammable, and similar to spirit of wine:) what remains, is oil of Saturn.

The caput mortuum may be reduced to lead. It is grey, inflammable, and odorous.

In the distillation, one part and a half of phlegm and spirit come over, and six parts of lead remain behind.

4. When a solution of calx of lead is evaporated, a pellicle forms, after which elegant, ponderous, white, and inflammable crystals are deposited.

A particular oil is supernatant, which may be converted into lead.

These crystals are convertible into a white, yellow, or red minial calx, and ultimately into glass.

5. A solution of sugar of lead turns yellow with a solution of nitre.

With fixed nitre it turns white.

Spirit of nitre does not change it.

It turns red with sulphur.

With salt of tartar it turns white and is precipitated.

With common salt the same.

It turns green and black with vitriol of copper.

Brown with vitriol of iron.

Grey with tin.

Red with solution of iron.

Black with solution of arsenic.

Transparent, though cloudy, with distilled water.

Ditto with water of quick-lime.

Ditto when a drop of spirit of vitriol is added to it.

It turns blue with turnsole *(calce viva œlandica).*

6. Lead is not miscible with gold; although gold and silver are purified by means of it.

7. Metals are lost in glass of lead; except gold and silver.

8. Lead becomes comparatively brittle by mixture with orpiment or arsenic; and by the use of water it may be made into minute globules or shot of exact rotundity.

9. Lead is converted into ceruse as follows; First, the metal is made into thin plates: these are then rolled into cylinders, and placed in an earthen vessel, one-third full of sour beer, but they are not allowed to come in contact with the fluid. The vessel is then buried in horse-dung, and in four weeks the lead is converted into ceruse, which, when twice ground with stones, and dried in the sun, forms the white lead so extensively used in colours.

It was our intention to have proceeded to the consideration of the other metals in succession, and at this stage particularly to have spoken of Silver, to the particles of which we have assigned the figure represented in Fig. 24.* For it is with no small pleasure we have found that the weight of this metal, its crystallization, its arborescent transformation under peculiar circumstances, its combination with acids to form lapis infernalis, and with salts to form luna cornua, as well as all the changes of colour that it undergoes, by our rules, exhibit the most exact accordance with the mechanism of this supposed figure. On second thoughts, however, we deem it best to wait a little before proceeding farther. Nevertheless we will here mention by anticipation the experiments on silver and mercury.

EXPERIMENTS ON SILVER.

1. The matrices of the ore of silver are in part like lead, in part like iron or steel, in part like horn, sometimes like goose-dung. Their colour is red, white, and black.

2. Silver ore is tessulated, also radiated, and exhibits a variety of regular forms.

* No such figure is to be found in these *Specimens.*—*Tr.*

3. Lead ore is found with that of silver.

Mercury is sometimes found in silver ore.

4. Native silver sometimes occurs in a capillaceous form; sometimes in that of little balls made of silver threads; sometimes it is arborescent like a vegetative growth; at other times it is found in plates and leaves; and occasionally in solid masses.

5. Silver is almost as ductile as gold.

6. The weight of silver to that of water is as 10 to 1.

7. Silver is miscible with gold.

A quarter of a part of silver will whiten one part of gold.

8. The silver may be separated from the gold by acid spirits, provided it be previously reduced to powder by the agency of fire and water.

Silver amalgamates with mercury.

The silver may be separated from the mercury by being dissolved, and the solution made tepid and precipitated by common salt and water: after which the mercury may be distilled over into water, and the silver will be left in mass.

9. Melted silver is absorbed [*devorari*] by antimony.

10. Melted silver is absorbed by lead, but separated again by fire.

11. The melted silver coagulates in the centre of the lead.

A peculiar shining pellicle marks the beginning of the coagulation.

12. The scoriæ and litharge are of various colours, as red, yellow, silvery, &c.

13. Silver cannot be separated from lead in any furnace that contains lixivial salt.

14. Silver forms a sonorous compound with bismuth and tin.

15. Silver is insoluble in aqua regia.

16. One part in weight of silver is soluble in three parts in weight of spirit of nitre.

But little heat is needed for the purpose.

17. One part in weight of silver is soluble in two parts in weight of aqua fortis.

18. The solution is accompanied with effervescence; red fumes are given out, and more or less heat is disengaged.

19. The solution of silver in spirit of nitre is limpid.

The solution of silver in aqua fortis is white.

20. Solutions of silver are intensely bitter to the taste.

21. They are to the last degree corrosive, and act as caustics on the hands and skin.

Mixed with sulphur, the solution of silver first turns yellow, then red, and at last black.

With quick-lime it turns pale brown: with vitriol of iron, pale yellow: with a weak solution of copper, green: with decoction of ore of antimony, milky: with common salt, the same: also with spirit of common salt: with spirit of hartshorn, pale yellow: with salt of sabine, yellow: with ley of calcined oyster-shells, brown: with salt calcined with sulphur, it turns white, yellow, and red.

22. Nitre combines easily with solution of silver.

23. When the solution is evaporated, crystals are deposited.

If a solution of silver in spirit of nitre be evaporated, crystals or lamellated masses are obtained of vitriolum lunæ.

24. The crystals of silver are intensely bitter.

25. When the solution is evaporated, a pellicle forms.

26. After the solution is accomplished, something like oil remains at the bottom of the vessel.

27. Silver in solution is precipitated in a white powder by common salt.

When spirit is let fall in drops into a solution of silver, the latter turns milky, and a perfectly white powder is deposited.

When there is too little water, the crystals that form are confused: when there is too much, there is no crystallization at all.

LAPIS INFERNALIS.

28. When a solution of this substance is evaporated, crystals are deposited; and if the oil in the crucible is expelled by a great heat, the mass that is left is fiery and corrosive.

When these crystals are dissolved in a cellar, the result is lapis infernalis.

Eleven parts of lapis infernalis are obtained from twenty-four parts of the evaporated solution.

29. CHRYSTALLI LUNÆ.

Silver in solution is precipitated in white powder by common salt; in like manner the crystals in solution.

The crystals are intensely bitter to the taste; and virulently caustic to the hands and the skin.

The crystals are as soluble in water as common salt.

The crystals are heavier than the silver.

When the crystals are distilled, they yield a peculiar liquor.

The crystals of silver deflagrate and crepitate in the fire, the same as those of nitre.

The powder left after the deflagration is pure silver.

The caput mortuum that remains after the distillation of chrystalli lunæ, is insipid, like that of common salt.

LUNA CORNUA.

29½. One part of silver dissolved in two parts of aqua fortis, and precipitated by common salt, and subsequently edulcorated and fused over the fire, constitutes the substance termed luna cornua.

Luna cornua is transparent, like horn or glass.

Luna cornua is insipid.

Luna cornua is not soluble in aqua fortis or aqua regia.

Luna cornua is peculiarly fixed, and may be melted a thousand times without relapsing into silver.

Luna cornua is malleable.

Luna cornua melts like wax in the flame of a candle.

Luna cornua may be revived by the agency of lead.

ARBOR LUNÆ.

30. If one part of silver be dissolved in three parts of spirit of nitre, and two parts of mercury and twenty of pure water be added, and the mixture set aside for forty days, an arborescent crystallization will take place, and the tree will be complete with stem, branches, and balls of fruit at the end of them.

This tree,—the arbor lunæ,—forms better in a cool than in a warm place.

The tree is resolved if the vessel is in the least disturbed; but after a time it grows again.

If there be less than the above proportion of water, viz., twenty parts, the crystals will be confused.

If there be more than twenty parts, crystallization does not take place.

31. Silver is blackened by the fumes of sulphur.

32. Melted silver looks as black as iron.

33. A part of the silver is said to fly off in a vitreous smoke.

34. The silver may be precipitated by pouring water upon it, and placing a piece of sheet copper in the mixture.

As the copper dissolves, the silver is precipitated in scales.

The copper so dissolved may be precipitated by a plate of sheet iron.

The iron in its turn may be precipitated by lapis calaminaris. And the lapis calaminaris, by nitre.

35. Nearly the whole weight of silver is precipitated on the plate of copper.

EXPERIMENTS ON MERCURY.

1. Mercury weighs to water as 14 to 1 nearly.

2. Mercury is divisible into most minute particles.

Mercury will permeate the human nerves, and has often been found in the bones of the cranium. On account of its penetrating fineness, those who handle it are apt to become paralytic.

Mercury has the power of permeating metals.

3. When mercury is placed over the fire, it flies off before it can become red hot; but without any appearance of smoke.

4. Mercury is very cold, and also very hot.*

5. Mercury amalgamates with gold, silver, antimony, and sulphur.

6. Gold is dissolved by mercury, and reduced to an impal-

* The author here seems to allude to the conducting power and capacity for heat of this metal. Owing to the different significations in the terms, as used by the older and more modern chemists, the present work will require a very liberal construction from the courteous reader.—*Tr.*

pable powder; but this powder regains its former condition when exposed to the action of fire.

7. Mercury in contact with iron will not penetrate or dissolve it; and therefore it is best kept in iron vessels.

8. Mercury is found in native cinnabar: and in gold mines and silver mines.

9. When mercury is shaken in vacuo, it emits a faint light; and a drop of it let fall under the same circumstances, presents the appearance of a fiery shower.

When shaken as above, it shines the most as it ascends in the vessel, and the concave parts of it are brighter than the rest; and as it falls, it describes an immense variety of figures.

10. Mercury is dissolved by oil of vitriol with smoke and crepitus.

11. Mercury is readily dissolved by spirit of nitre; seventeen parts by weight of mercury being soluble in twenty-two parts by weight of spirit of nitre.

While the process of solution is going on, effervescence takes place, attended with the disengagement of red fumes.

12. Mercury is soluble in aqua fortis.

At first the solution is green, but afterwards becomes colourless.

13. Mercury is soluble in hot water.

14. Mercury is soluble in aqua regia.

15. When the solution evaporates, it deposits white and corrosive crystals, which can hardly be kept in a dry state, and exhale a red vapour.

16. Mercury dissolved in spirit of nitre, is precipitated spontaneously, or by evaporation.

A white mass forms at the bottom.

This white mass is corrosive, and can hardly be kept in a dry state.

This white mass turns yellow with lime water, and loses its corrosive properties.

If the evaporating heat is continued, the mass becomes red.

Eight parts of mercury with nine of spirit of nitre, yield nine parts of precipitate.

The spontaneous precipitate of mercury is soluble in spirit of

nitre; also in spirit of salt, and in aqua regia; but not so readily in oil of vitriol.

17. If mercury be dissolved in aqua fortis, and precipitated by means of evaporation; and if the remainder of the fluid be driven off, a white corrosive powder is produced, which can hardly be kept in a dry state.

This precipitated powder emits dense red fumes.

If it be stirred about in an alembic, it loses its white colour, and turns red.

18. If mercury be dissolved in oil of vitriol and precipitated, the mass at the bottom of the vessel is white like snow.

When oil of vitriol is added to the mass, it becomes comparatively fixed, and austere to the taste.

By adding still more oil of vitriol, it becomes a fiery, metallic, and corrosive oil.

If the powder be washed in water, it becomes of a citrine yellow, and forms what is called the panacea of Paracelsus.

19. If the corrosive precipitate be powdered, mixed with twice its weight of water, and agitated, and set aside in three vessels; then,

1. On dropping a little oil of tartar into the first vessel, a red precipitate is thrown down.

On adding spirit of sal ammoniac to the same, a white precipitate is thrown down.

On adding oil of vitriol to the same, effervescence takes place, and the mixture becomes limpid like water.

2. On dropping a little sal ammoniac into the second vessel, the mixture turns white.

3. By a little lime added to the third vessel, it turns yellow.

20. Mercury dissolved in water, turns milky on the addition of a few drops of spirit of urine; becomes limpid again by aqua fortis; and once more milky by spirit of urine.

21. Mercury is rendered opalescent by urine.

With urinous substances, it first takes on a thin cloudiness, then a milky consistence, and at last it falls in an inspissated condition to the bottom.

It reddens with fixed alkali, and the change of colour is considerable, just in proportion to the quantity of alkali made use of.

Quick-lime causes it to turn first white, then yellow, and lastly red.

With solution of vitriol it becomes opalescent.

The same with quick-lime.

Oil of vitriol makes it limpid.

Solution of alum, opalescent.

Distilled aqua petrolei, the same.

It becomes opaque white with spirit of wine.

Yellow, with caput mortuum of nitre.

Black, with sal anethi.

With solution of sulphur per tartarum, it first reddens, and then turns black.

Common salt calcined by sulphur makes it first black, and soon afterwards greyish white.

With light blue clay, it is in the first instance limpid, next it becomes white, then light brown, with small clouds suspended in it.

The solution of mercury in aqua fortis,

Is turned black by spirit of sal ammoniac.

First milky, and then red, by oil of tartar.

White, by solution of salt.

Black, by scoriæ of antimony.

22. Mercury in solution is precipitated by common salt.

Also by sal ammoniac.

23. If a solution of mercury in spirit of nitre be precipitated by common salt or sal ammoniac, the precipitate will be white.

If oil of vitriol is substituted for sal ammoniac, the precipitate is red.

Acid spirit of vitriol dropped upon this red precipitate, causes it to dissolve without effervescence, and the solution itself is red.

When spirit of salt is used instead of vitriol, the solution is white.

Spirit of sal ammoniac dropped upon the red precipitate, turns it grey.

If a large quantity of water be added, the mixture itself becomes like water.

24. The precipitates of mercury may be revived by distilla-

tion with quick-lime, lead, iron filings, alkalis, triturated charcoal, tin, &c.

25. ARTIFICIAL CINNABAR.

Mercury amalgamates with sulphur; in fact, when sulphur is powdered and rubbed in a mortar with mercury, the metal is killed.

If this mixture be sublimed, cinnabar is obtained.

If one part of sulphur be mixed with three parts of mercury, and the mixture be powdered and sublimed with quick-lime at a moderate heat, the result is eleven parts of mercury and twenty-four parts of cinnabar.

Mercury mixed with sulphur loses its corrosive properties.

Cinnabar is intensely red.

Mercury is found in native cinnabar.

Mercury will amalgamate with vitriol.

26. Mercury is restored by the caput mortuum of vitriol, or of nitre.

27. Mercury may be purified by red brick-dust, by melting in wax, by boiling in vinegar; also by nitre, spirit of turpentine, &c.

With regard to the other metals, as tin, iron, copper, antimony, gold; and the various salts, vitriolic, alkaline, aluminous, sulphurous, &c., — we shall treat of them, God willing, at another opportunity.

END.

NEW

OBSERVATIONS AND DISCOVERIES

RESPECTING

IRON AND FIRE,

AND PARTICULARLY RESPECTING

THE ELEMENTAL NATURE OF FIRE:

TOGETHER WITH

A NEW CONSTRUCTION OF STOVES.

FIG.1.

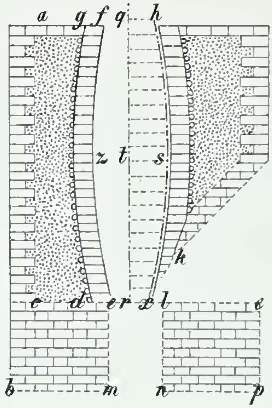


FIG.3.

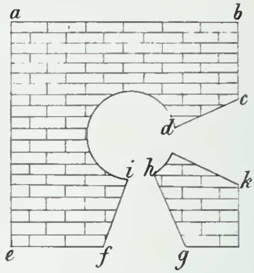


FIG.4.

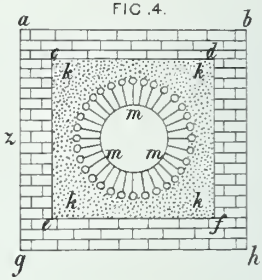


FIG.5.

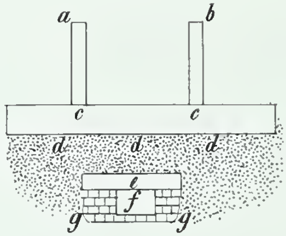


FIG.6.

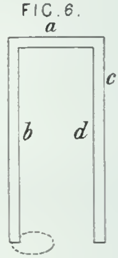


FIG.7.

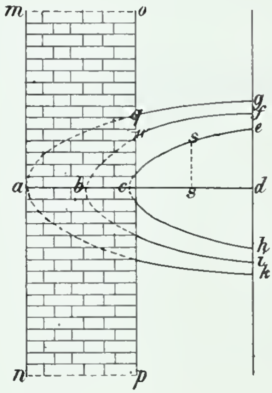
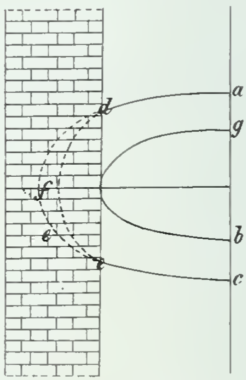


FIG.8.



NEW OBSERVATIONS AND DISCOVERIES,

ETC., ETC.

New Observations and Experiments upon Fire, Iron, and its scoriæ, from actual data collected from the workmen at a large iron furnace; shewing also the construction of the furnace.

DESCRIPTION OF THE LARGE FURNACE.

The nature of fire cannot be more satisfactorily investigated anywhere than in metallurgic furnaces and foundries, which are of great size, and render palpable to our senses the effect of fire upon metals and hard bodies. And as the furnace in which iron ore is smelted is the largest of all those that are devoted to metals, so we think it worth our while to give an account of its construction in the present work.

The furnace is shewn in Fig. 1, where we have to remark, 1. Its cavity, *qtr*; the height *qr* is about fourteen ells; the circumference *fh* is nine ells; the circumference *el* about the fireplace is seven ells; the circumference of the belly *zs* is twelve ells; and the cavity itself is capable of containing about two hundred tons of charcoal. 2. The wall lining the cavity is represented by *gfde*; it consists of a blue kind of stone, generally scissile, which resists the fire extremely well; some furnaces, however, are lined with a black stone. 3. There is a layer of smaller stones beyond this wall. 4. The space beyond these stones is filled with various sorts of sand, clay, fine ashes or scoriæ, and dross, as at *agcd*. 5. On the exterior the wall consists of large stones, intersected and bounded by large timbers, to give it greater firmness. In some furnaces, there is no

timber-work, but the wall is covered with common grey or red brick. 6. The foundation *cdbm* is of stone. 7. On two sides there are apertures *xl* with a slope *xk;* this slope is supported by iron bars placed transversely; one of these apertures is used for the bellows, the other for the workmen, and for letting out the ore. 8. When the furnace is built, the dimensions of its cavity and curvature are taken according to the scale *qrs,* which is curved in the ratio of the lower and upper diameters; whence the line *qsx,* along which the wall is built, is a hyperbola. 9. *erx* is the fire-hearth on to which the melted ore flows, as will be mentioned hereafter. 10. The foundation is shewn in Fig. 2, where the reader will perceive that there is nothing in the front part, because the bottom of the hearth is there, and has no weight of wall above it. 11. The horizontal section of the same furnace is shewn in Fig. 3, where *ih* is the anterior aperture for the emission of the metal; *d* is for the bellows; the remaining parts are built of stone. The distances or spaces *fg* and *ck* gradually approach together by an obliquity in the perpendicular wall. 12. The upper horizontal section is represented in Fig. 4, where *abgh* is the outer stone wall, which is also enclosed by the framework of the beams *cdef.* *kkkk* is the accumulation of sand, dust, dross, &c. *mmm* is the internal wall consisting of the above-mentioned stones, which are placed with their long diameter pointing towards the central line of the cavity. 13. *mk* is about three feet in thickness, *kz* is three feet and a half, the interval *k* is dust and sand. 14. The shape of the outside is square. 15. Clay with one-third sand is used for joining the stones together, on account of the intensity of the fire.

The representation of the fire-hearth or place into which the melted iron ore runs, and where it is in a measure separated from its earthy part, is shewn in Fig. 6; and its situation in Fig. 1 is at *erx.* It is to be observed that, 1. It is formed by three calcareous stones, *bad,* Fig. 6. 2. The height of each of these is about a foot and a quarter. 3. The length of *a* is a foot and three quarters; that of *b* or *d,* three feet and three quarters. 4. The bellows or blast fit into the part *c;* and *f* is the aperture through which the melted metal runs out: *e* is a kind of thick iron shutter.

The foundation or bottom of this fire-hearth is shewn in Fig. 5. *ab* is the fire-hearth already mentioned. 2. *cc* is a large square stone, about seven feet in breadth, and one foot thick. 3. Under this stone there is a quantity of sand *ddd*, to the same depth. 4. Beneath the sand, there is a thick iron plate *e*, about eight inches in depth, which covers a small passage *f*, to allow the evaporation of the water.

EXPERIMENTS.

§ 1.

When the smelting operations are about to be commenced in the above furnace, the usual practice is, to fill it from the bottom to the top with charcoal, and then to introduce a little fire, which soon becomes diffused throughout the mass of charcoal. The furnace is then closed on every side with iron plates placed upon it for ten or twelve days, by which the fire is indeed put out, but the charcoal still preserves an intense heat, which likewise penetrates into the wall during those days; we have now to observe that,

1. After the lapse of ten or twelve days, when the furnace which had been covered over with the plates is again opened, the charcoal in it appears of its own natural blackness.

Not a spark of fire is discoverable in the charcoal, although it is exceedingly hot.

The heat remains in the charcoal for ten or twelve days, although it had been covered in on all sides.

The heat must have been increased, for it penetrates the wall to the depth of a foot.

2. During the twelve days, the mass of charcoal has subsided under the influence of the heat only from one to two ells; that is to say, it has, in that time, diminished only one-tenth in bulk.

3. The same result has been found to take place with wood; which on one occasion was packed into the furnace, instead of the charcoal, and there inclosed on all sides; notwithstanding which, the heat remained in it, and converted the ligneous substance into carbonaceous.

We may conclude from these experiments, *in the first place,* that fire or heat will live in wood and carbonaceous substances, although it is inclosed and thoroughly covered in. *Secondly.* That the heat increases more and more and penetrates into the very wall. *Thirdly.* That it will continue for a whole month without much consumption of fuel. *Fourthly.* That stoves may be constructed on this plan, affording much caloric for a great length of time without much consumption of fuel: and that fire may be controlled and proportioned to the uses required of it, just as well as streams of water. On these subjects see our New Construction of Stove.

§ 2.

When the plates are taken away from the furnace, *i.e.* when the latter is opened, the charcoal is of the natural blackness, although at the same time extremely hot.

1. About a quarter or half an hour after the furnace is opened, fire and flame spontaneously burst forth among those pieces of charcoal on the surface, in consequence of the simple contact of the atmosphere, and ignite the whole mass of fuel.

2. This eruption of fire and flame is only observed in the part exposed to the air, or directly under the aperture itself; and not in any part that is still covered by the plate.

3. As the charcoal had sunk down in twelve days one or two ells in depth, we perceived a piece not well burnt, in a crack of the wall. This piece, although it was simply hanging to the wall, began to ignite as soon as it came in contact with the free and open air.

But the flame was extremely volatile, and merely played over its surface, without one visible spark in the charcoal itself.

From these observations it follows, that when the carbonaceous mass is subjected to an intense heat, it produces a sort of phosphorus or nitrous powder, which bursts into flame as soon as it meets with the free air. The causes of this phenomenon may be seen in our *Principles*.

§ 3.

1. When the furnace is opened and filled with charcoal, the ore is at first placed in the middle, or over the central line of the furnace, about once an hour.

2. On the first day, only five loads of ore are put into the furnace at once; on the next day, seven loads; for if more be thrown in, it does not melt; on the third day about nine; on the fourth, ten; on the fifth, eleven; and so on in the same proportion, till on the fourteenth day twenty loads are cast in. This is the limit of the quantity.

3. On the first day, the ore is only thrown into the middle, or over the central line of the furnace; on the next day, it is placed a little way from the centre; on the third, at a greater distance; and at length on the sixth and eighth days it is thrown all round up to the very walls.

4. If the number of loads of ore is increased too rapidly, *e.g.* if twenty loads are thrown in within ten days, the fusion does not take place so well; but about the fortieth or fiftieth day becomes checked, so that the ore cannot be easily melted without the furnace being somewhat cooled.

These experiments clearly show, that the great stone wall cannot receive the degree of fire that there is in the charcoal in less than fourteen days; but by its coolness, moderates and diminishes the heat in the fuel; so that during the first few days the furnace is unable to melt more than five, seven, nine, ten, &c., loads.

Hence we derive the following rules. 1. The power of the fire increases from the periphery to the centre in a parabolic ratio; that is, as the ordinates to the axis. 2. The power of the fire increases in hard bodies likewise in a parabolic ratio. 3. But when the fire penetrates into hard substances, it increases through equal distances in an equal space of time, or in the simple ratio of the time and distance. For example, in Fig. 7, Plate I., let *gkpo* be the furnace full of charcoal and fire; *gfed* the central line of the furnace, *op* the cold wall, but into which the heat penetrates in course of time. Now we say that, *in the first place*, the degree of heat is in a parabolic ratio; that is to

say, the heat at *d* is to the heat at *s* as the ordinate *ed* is to the ordinate *ss*, if there be no heat at *c*. *Secondly*. If the heat has entered into the wall as far as *b*, and if the same parabola be described, the heat at *c* is to the heat at *d* as the ordinate *wc* to the ordinate *fd*. *Thirdly*. If the heat has penetrated into the wall as far as *a*, and the same parabola be drawn, the degree of heat at *c*, or at the inner surface of the wall, is to that at the centre *d*, as the ordinate *qc* to the ordinate *gd*; as is plain from the experiments.

It is well known that in parabolas, the axes are in the duplicate ratio of the ordinates, or as their squares; that is, *cs* is to *cd* as the square *ss* to the square *ed*, and so on. If now on the first day the heat in the centre be five; on the second day, seven; on the third, nearly nine; on the fourth, ten, and on the fourteenth, twenty, then these are also the degrees of the fire in the same times, that is, *de*, *df*, *dg*. These times are as the squares of the power of the fire, or as $5 \times 5 = 25$; $7 \times 7 = 49$, or 50; $9 \times 9 =$ about 75; $10 \times 10 = 100$; $11 \times 11 = 121$, or about 125; $20 \times 20 = 400$. The periods of time are equal to these divisions, as 25, 50, 75, 100, 125, 150, 175, 200, and at length on the fourteenth day $14 \times 25 = (350)$ nearly 400. The difference is thus always 25, so that the times are equal when the power of the fire is augmented in the duplicate ratio, which exactly coincides with the results of experience.

These experiments likewise prove how exactly fire obeys this rule; for if the above proportion be not scrupulously observed, a loss of fusion is certain to occur subsequently. Thus if the fire be compelled to penetrate into the wall more rapidly than in the above ratio, so that the power of the fire at *f*, Fig. 8, is greater than the parabola requires, and the curve in consequence becomes somewhat broader, as *fda*, then this power must be restored at some future time, until the true figure or proportion of the parabola is regained. Hence if there be any cold substance, such as water, on one side, the fire cannot penetrate into the hard body, and follow the rule, because the coldness of the water prevents the moments of the calefaction from being as the squares of the forces of the augmented fire. Just as water in a leaden vessel exposed to the fire prevents the heat from increasing in the lead, and above all prevents the lead

from melting, because the aforesaid rule of the distances and times cannot be obtained. By this proportion, it follows, that if the distance be double, the fire in the centre is augmented from 5 to 7; if it be fourfold, from 5 to 10; if eightfold, from 5 to about 14, and so on with the remaining distances.

§ 4.

Respecting the proportional quantities of ore and charcoal, it has been ascertained, that,

1. The proportion varies according to the construction of the furnace.

In the best furnaces, the weights of ore and charcoal are equal.

But in proportion as the charcoal is heavy, less of it is needed.

These facts afford grounds for concluding, that as much fire exists in any quantity of charcoal as in the same weight of ore, or that the fire is augmented so much in the large space as to enable it to reach the same proportion with the degree of heat in the smaller space, that is to say, in hard bodies. Otherwise the fire in the stones is much more intense than that in the wood, and it follows a proportion about the same as the specific weight or compactness of the substances; but it seems that in soft bodies, and in those that are not very hard, as wood for instance, the heat may, by the multiplication of the space, be brought to equal the degree that it attains in hard bodies.

But when, during the first fourteen days, the ore is melted in the great furnace, various signs are afforded by the ore, as well as by the flame and wall, to enable us to judge whether more or less ore or charcoal is required. These signs are the following:

1. If the scoriæ are beset with minute shining plates, like scales, it is a sign that more ore is required.

2. In proportion as the scoriæ are white, especially at the edges, more ore is required.

If they are black, less ore is wanted.

3. If the mass of pig iron be as it were polished and smooth, more ore is required.

4. If the scoriæ be covered by a sort of rust, or reddish colour, it is an excellent sign.

5. If as the drops fall (which may be seen through the orifice for the bellows), they are black, more charcoal is wanted. If they are white, more ore must be added.

The best sign is when the white and black drops are seen in equal quantity.

6. If the external part of the wall turns green from the flame and smoke, more ore is required.

The upper part of the furnace affords a similar indication.

But if it becomes black, more charcoal is necessary.

7. If the mass of pig iron, when broken, is like silver or ice, more charcoal is required.

8. If the stream of iron emits sparks as it rushes out, more charcoal is wanted.

9. If a flame, or white smoke with sparks, rises to a considerable height out of the furnace, the charcoal is then being consumed unduly.

The causes of these phenomena may be seen in our *Principles.*

§ 5.

There are many particulars worthy of observation respecting the scoriæ that issue from this large furnace; thus,

1. The scoriæ of pig iron congeal almost the instant they flow out.

2. The parts that are the first to congeal, as the ends and thin portions, undergo vitrifaction.

If a piece of cold iron be plunged into the melted ore and then withdrawn, the scoriæ appear sticking around it; but those that are next the iron are converted into pure and brilliant glass.

This however is not the case with those which are at a distance from the iron: but on these matters, see our Theory of Glass.

3. If the scoriæ run out of the furnace over damp sand, they swell up like froth.

4. As the scoriæ are running out, they emit sparks, which are pure iron.

When this scintillation ceases, the matter on the surface of the scoriæ swells into bullæ, in which a large quantity of ferruginous powder is found.

5. That kind of scoriæ which comes out after the bulk of the iron, and runs over the masses, obstinately resists the action of fire, although not that of moisture.

Such scoriæ are heated by very little fire.

The influence of the fire renders them exceedingly tenacious; in fact, like glass.

These scoriæ may be very serviceable in stoves, because they resist the power of the fire exceedingly well, and when heated by even a small fire, give out some warmth: they will also keep for a century without any visible change. Owing to these qualities, they are now made up into bricks and sold in the neighbourhood, and would be an excellent article for exportation. The following general remarks apply to them:

6. They differ according to the ore they come from.

They are useful in proportion as the ore contains less stone.

7. The scoriæ are of a different quality in those furnaces where the iron is rendered malleable.

These scoriæ are reduced to a very fine powder by water.

Iron melts and runs better by the addition of these latter scoriæ, but not of the former, &c., &c.

§ 6.

Respecting the blast, we have to observe, that in this furnace the bellows are large, being twelve feet long, six wide, and four deep; they are made of wood, and are good in proportion as they are heavy: they work about six hundred strokes in an hour. With regard to the blast, it is to be remarked, that,

1. If the position of the bellows be too horizontal, the wind flies off, and rises upwards without producing its due effect upon the ore.

If the position be too oblique, the melted ore cools about the orifice for the bellows.

The best result is obtained when the plane of the blast is inclined at an angle of fifteen degrees.

2. If the aperture of the blast be larger than the just proportion, more air is indeed blown out; but it is dispersed before it can get to the opposite side.

3. When the tubes of the bellows are at a certain distance from the aperture, they blow more powerfully than when they are too near.

4. If the upper part of the furnace be wider than it should be, the wind escapes without producing its due effect on the fire and ore.

If it be too narrow, the reverse is the case.

5. The furnace is efficient in the blast, in proportion to its height.

The nature of the blast is very different in other metallurgic furnaces, which are smaller; for example, in the puddling furnaces, where the crude iron is smelted a second time, and rendered malleable. The aperture through which the blast enters, is furnished with a sort of copper cone, having an orifice of a semicircular form at the narrow end, which is thrust for some distance into the furnace; the other end is comparatively broad, and receives the pipes of the bellows. On this head we have to observe, that,

1. The aperture or copper cone is of utility in melting the iron, in proportion as it is carried deep into the furnace.

If it is not sufficiently prolonged, the surface near the pipe will whiten; which is a sign that the fire is not raised to its due intensity by the blast.

2. If the cone is too horizontal, much charcoal is burnt.

If it be too oblique, very little charcoal is consumed, and the iron is melted with difficulty.

In general it is so placed, as to enable the blast to strike against the lower part of the opposite surface or wall, or to have the iron beneath it.

3. If this vent forms an angle with the furnace, the metallic iron is consumed, and converted into a species of scoriæ.

4. The semicircular orifice of the blast must be turned to suit the character of the iron, and its plane must be set either obliquely or horizontally.

If the iron be impregnated with sulphur, the plane ought to

have an inclination of thirty degrees, so that the blast may cut the mass of iron over against it like a knife.

But if the iron be of a different kind, the arrangement must be different.

The following observations apply to the crude pig iron that has been smelted a first time.

1. In this furnace, a twentieth part of lime-stone is required as a flux for the iron ore.

It is also found that the iron ore may be fluxed by the addition of flint or silex.

The lime-stone must be placed on the mass in the central line of the furnace.

And in the same quantity on the first as on the subsequent days.

2. This crude iron of the first melting is of the best quality when of a grey colour.

When the colour becomes silvery, or the iron has the appearance of ice, it is of less value.

3. The iron becomes of an icy or silvery hue, when too small a quantity of charcoal is used.

And also when it is quenched too suddenly in water.

In the thinner parts, as in the extremities of the mass, the iron wears a silvery and icy colour, but not in the mass itself. The reason is, that the extremities cool too suddenly.

When the crude iron is about to vitrify, it first assumes a silvery colour; which colour therefore is a step towards vitrifaction.

This icy or glacial iron is very brittle;

And also lighter than the grey iron.

4. Melted iron is red: but the scoriæ are yellow, or verging to white.

Melted iron runs down an inclined plane with the same velocity as water.

The scoriæ run separately in the stream, forming a kind of thick thread upon the top of the liquid iron; and distinguishable from it by their peculiar colour.

5. Iron congeals sufficiently in two minutes to resist the thrust of a stick.

A mass of iron two feet long, one foot broad, and three-fifths of a foot thick, will cool in less than twelve hours.

§ 7.

Respecting the fire, the following particulars may be observed:

1. The fire that bursts out beneath is of different colours, according to the proportions of the charcoal and ore.

Sometimes it is red, sometimes yellow, at others bright white, sometimes green.

2. The flame that comes out of the furnace from above forms a very thin sheet about the edges.

This eruption of the flame appears to take place in a certain gyre, or in a spiral direction.

This flame is attended with a sound or noise, as of running waters.

The upper part of the furnace is rendered smooth and polished by the stream of fire.

3. The fire is most intense in the middle of the furnace, because that part is the widest; it being found that the ore first melts there.

If the belly of the furnace is wider, or narrower, than it should be, the ore melts more rapidly, or more slowly, than it ought.

The furnace appears to be eaten away chiefly about its belly.

4. When the melting is performed, the walls of the furnace are as much damaged by a small degree of heat as by a large.

After the work of melting is done, the heat for the first time penetrates through the wall, and may be felt on the outside: not so whilst the works are continued, although they should be in active operation for two-thirds of a year.

5. In the fire, the charcoal has the appearance of the whitest and lightest snow.

Such pieces of charcoal as are shut in by scoriæ are not in the least consumed.

The charcoal is consumed and diminished in layers only.

6. When a liquid mass of iron runs over a small quantity of

water, the volume of metal first swells, then froths up like water, and at last is thrown up to a height of from thirteen to twenty yards, to the great danger of the by-standers.

If scoriæ, and especially those of copper, be suddenly and carelessly thrown into a trough of water, they frequently split and fly in pieces, and are projected about in granules with a noise like that of a gun, and to the imminent peril of all who are near. So great is the power of fire over water, or of water dilated into vapours.

§ 8.

With respect to the furnace itself, it has been observed, that,

1. If the place where it is erected be damp, the operation of smelting is badly performed; the ore is difficult to liquefy, and sometimes congeals on the sides of the lower part of the furnace.

If the foundation be too dry, the lime-stones at the bottom are frequently destroyed, together with the metal, by the action of the fire, whereby a great loss of iron is occasioned.

2. The furnace is in the best condition for use when it is vitrified; that is, the second or third time of smelting.

When it is old, its effect on the metals is lost.

3. In the remains of old furnaces, it has been observed, that,

The heat had entered into the stones to a depth of nearly two feet.

The clay cement of the stones next the fire was changed into glass of a white colour; behind which, the glass was yellow, then green, and lastly blue.

Beyond the blue glass, and at about nine-tenths of a foot from the cavity of the inner wall, a red, greasy, and oily substance was found, which was the first stage towards vitrifaction.

More inwards, the brick was red, then yellow, and at last white; but it was very brittle, and broke into granules.

The small pebbles in the sand were exceedingly white.

4. The stones themselves were of a colour verging to red: passages and ducts perpendicular to the fire were visible in them.

But the part which was next the fire had swelled a little, and was converted into glass.

Many noteworthy particulars concerning fire, iron, copper, &c., may be gained from other metallurgic furnaces; but of these, God willing, we propose to speak at another opportunity.

§ 9.

As we are now treating of iron, and of the ore of that metal, we will here add, by way of appendix, certain other experiments on the subject, and these not performed by the vulgar class of workmen, but by scientific persons; nor in large furnaces, but in chemical laboratories. And this we do with especial reference to the use of those who desire to explore the internal mechanics and the deeper qualities of this metal. We must however be brief.

1. Iron weighs to water as $7\frac{4}{5}$ to 1.

2. Iron is very ductile when hot, and in this state may be drawn out into threads.

Iron is also ductile when cold.

Some iron is brittle when hot, and *vice versâ.*

3. Iron becomes hard steel if cooled down suddenly in oil, ashes, ley, salt, nitre, horns, or tallow, &c.

Steel may be re-converted into soft iron in the fire.

The best steel is made of rusty iron.

Steel does not rust so readily as iron.

Steel gives out sparks when struck against flint.

Steel is lighter than iron; and in the metallurgic furnace floats upon it like a ball.

4. The best and most ductile iron is of a greyish tawny colour, and consists of nothing but filaments and layers.

Iron of a silvery colour is comparatively worthless, and very brittle.

5. The toughest iron will become brittle from intense cold.

6. Iron may be made red hot by being subjected to a tremulatory motion.

7. Iron expands when heated, but contracts when cooled.

8. Iron is fixed in the fire, and is very difficult to melt.

9. Iron is easily vitrified.

10. Iron is not miscible either with gold or silver.

Iron does not mix or amalgamate with mercury; and hence mercury is conveniently preserved in iron vessels.

11. The ore of iron is rich; and frequently contains forty, fifty, or eighty *per cent.* of metal.

Iron ore is found in mountains, in stones, in ochre and bole, and iron is found almost in the native condition in sand.

The magnet is often found in iron ore; or the magnet contains a considerable quantity of iron.

12. Iron easily rusts; especially in the morning dew, in salt water, and in acids.

13. If the rust of iron be boiled and evaporated, it yields very little salt.

Iron corroded by rust burns with a blue flame.

14. When iron filings, sulphur, and water are mixed together, heat is produced.

If the mixture be in large quantity, it spontaneously emits a peculiar flamc.

It may be calcined into crocus, one part and a half of which may be obtained from one part of iron.

15. One part of oil of vitriol with twice its weight of water, poured upon iron filings, gives out a great heat; frequently accompanied by froth and ebullition.

It gives an odour of sulphur.

The taste is sweetish, like that of vitriol.

16. If iron filings be mixed with sal ammoniac, and submitted to a sand-bath, very volatile fumes arise, of different colours, and which adhere to the sides of the vessel; these may be sublimed into flowers, which in their turn, if placed in a cellar, will deliquesce into a peculiar oil.

17. When red crocus of iron is exposed to the air, it deliquesces into a golden-coloured oil.

This red crocus is soluble in vinegar, in Rhenish wine, and in hot water.

18. If spirit of wine and oil of vitriol be placed in an iron vessel, a peculiar vitriol or salt is thereby produced.

Two parts in weight of spirit, and two of oil of vitriol, produce five parts of this vitriol of iron.

19. Vitriol is precipitated by the presence of iron.

20. Iron is readily soluble in many acids.

Iron is soluble in aqua fortis; and with heat.

21. The solution of iron has a sweet taste.

It is of a hyacinthine colour.

It is not altered by quick-lime.

It turns red with a solution of the sugar of lead.

Fixed nitre turns it brown.

It is reddened by spirit of tartar.

It turns green with sal ammoniac.

Likewise with spirit of wine.

It turns black with urine.

The solution of iron by alum is blackened by the scoriæ of the regulus of antimony.

The solution of iron in oil of vitriol yields a green salt, but in water becomes of a saffron colour, or of a yellowish red.

22. When a solution of iron is evaporated, a pellicle forms.

23. If the solution be evaporated until the pellicle appears, crystals are deposited.

These crystals are green; pellucid; soluble in water; and when exposed to a gentle heat, they lose their transparency and greenness, and turn yellow at the top.

If the heat be increased, they become white, and suffer calcination.

If the heat be still increased, they turn red, and in this state are what is termed colcothar of vitriol.

If the heat be yet again increased, these crystals, or this salt, sugar, or vitriol of iron, are converted into the astringent crocus of the same metal.

24. Iron thrown into a solution of copper is consumed by the aqua fortis, and the copper is precipitated.

The copper adheres tenaciously to the iron plates.

In the northern countries, the vitriol of iron is not precipitated by common salt, &c., &c.

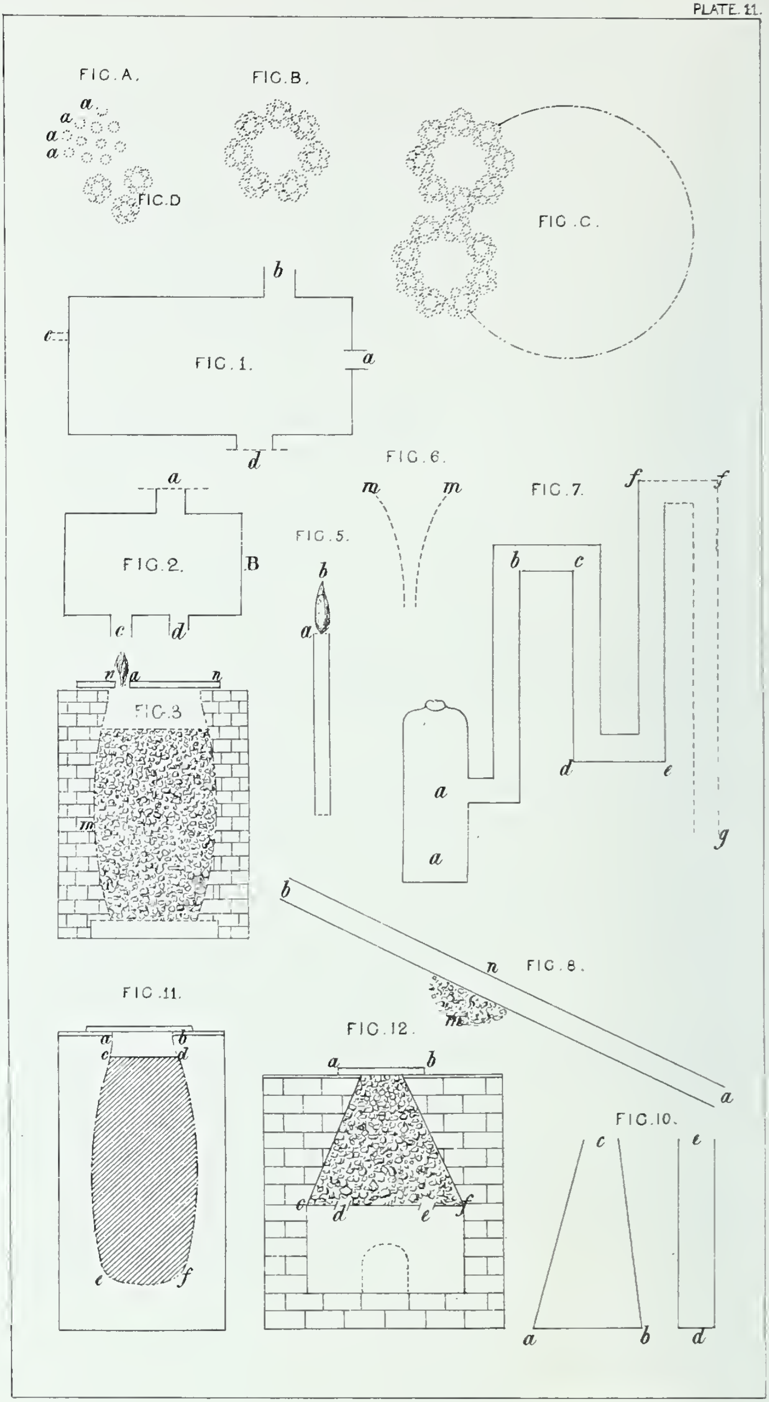


FIG. A.
FIG. B.
FIG. C.
FIG. D
FIG. 1.
FIG. 2.
FIG. 3
FIG. 5.
FIG. 6.
FIG. 7.
FIG. 8.
FIG. 10.
FIG. 11.
FIG. 12.

Rules respecting the Elemental Nature of Fire.

§ 1.

We shall here only speak of the elemental nature of fire, as we have already investigated its internal nature in a particular treatise devoted to that subject. It must be confessed that no subject can be more embarrassing to the mind than *the intimate mechanism of fire, and the nature of its particles.* In fact, fire exhibits so many varieties, such a ceaseless play of phenomena, and such a number of changes in substances from one extreme to the other, from the greatest heat to the greatest cold, and *vice versâ,* that the Theory of Fire seems to have occasioned more bewildering speculation than that of any other element. Nevertheless, we think that we have found rules that enable us to approximate in some measure to the natural mechanism of fire. Thus, 1. The particles of fire are purely bullular, like *aaaa,* Fig. A. 2. On their surfaces, there are mathematical points, or particles made up of points. 3. They are small and subtle enough to pass through all hard substances, whatever their composition; and in this their extreme minuteness, they are identical with the solar rays. And these particles may become larger or smaller, and form various bullæ, fine or ample, according to Fig. B, C, and D. Hence a very minute volume of them may occupy a large space, and *vice versâ;* nay, and fill all pores whatever, and extend without interruption, as a continuous element, throughout all bodies; varying only in different cases in tension and compression; which are often in proportion to the amplitude, or the fineness, of the pores, and often to the motion. Whence again it follows, that in our sublunary world

of nature there is nothing that this matter cannot pass through; in other words, there is nothing but may be pellucid, provided the passages through it are regular enough not to diffract this universal element, or subtle fiery matter, by reason of their figures. And it also follows that, 4. These particles are exquisitely mobile, owing to their superficial construction and amazing minuteness; for the less they are, the more mobile are they on their axes. But on these subjects see our Theory of Superficial Particles, &c., &c.

§ 2.

Many experiments have been made upon water as well as air, and indeed the industry of the scientific world has left us little further to know regarding their properties; but as for heat, it still constitutes an unexplored field. And yet if we examine its elemental nature, we shall find it to be almost identical with that of water and air, and only differing in weight and levity: so that while air or water tends downward, fire rises upwards; and as air or water acts in the lower regions, so fire acts in the upper. This however is plain,

Rule I.—*From the degrees of heat in closed places.* In places that are filled with heat, as for instance in rooms, the upper part is felt to be considerably hotter than the lower; and often when it is hot near the roof, it is cold on the floor; the difference being ascertainable not only by the senses, but by the thermometer; and shewing that the heat increases gradually as we ascend, and diminishes as we descend in the apartment. From this it might at first be inferred, that the element of fire or heat differs from the aqueous or aërial element in lightness only; for as water falls downwards and gravitates to the bottom in the ratio of its weight, so heat mounts upwards and aspires to the higher regions in the ratio of its lightness.

Rule II.—*From the horizontal surface of heat.* Preserving the same illustration of rooms or apartments, we observe in them that at a certain height a certain degree of heat is afforded; and that there is the same degree at the same height; as shewn by the thermometer. If we mark out a plane with a piece of string, and carry a thermometer about to any part of it, the

degree of heat will be found not to vary in the same plane, but to be greater in the upper than in the lower planes. In this respect, heat exhibits the same nature as water or air, with the sole difference of weight or lightness. Thus water keeps a horizontal level surface in its upper part, while heat, owing to its reciprocal or inverse properties, keeps the corresponding level plane at its lower part. It is, however, to be observed, that the result here may vary on account of the source of the heat or fire; for example, if at a little distance there be a stove to give out the heat, or an aperture through which the cold may enter.

Rule III.—*More heat escapes by the upper than by the lower parts.* If there be an aperture near the top of a warm room, then more heat will escape through it than through an aperture near the bottom of the same apartment. Thus it is found by experience, that more heat flies off through a small hole in the upper part of the wall, than through even a considerable gap in the lower. An opening of half a foot wide near the floor does not preclude the heat from being preserved in the building; but on the contrary, a few cracks or chinks near the roof are quite sufficient to render this impossible. Water and air are also identical in this respect. Thus when water is allowed to escape through an orifice, it runs out with greater velocity and in greater quantity when such orifice communicates with its deeper part, than when it is placed near the surface. In this point, therefore, these elements differ in nothing but in weight and lightness; that is to say, what water does in its lower part, that same thing heat does in its higher part; because when water descends, fire ascends, and *vice versâ.*

Rule IV.—*The escape of heat increases according to its altitude in the duplicate ratio of the times.* We before said that heat escapes more rapidly from an orifice near the roof than from one near the floor. Thus if a piece of paper, or a leafy branch, be placed against an aperture through which the heat is passing off, we shall see that the latter runs away in a torrent, and strikes with considerable force against whatever it meets in its way; but that lower down the effect is diminished; while near the floor the paper or leaves are drawn inwards; indicating that the wind rushes in at the lower opening, but when warmed,

it escapes by the upper. It has not yet been clearly shewn by experiment whether the velocity be, or be not, in the duplicate ratio of the time. It seems right, however, to conclude by analogical reasoning, taking into account the parallel properties of the elements, that the above increase of motion or velocity is in the duplicate ratio of the times; this being the demonstrated ratio which is observed by falling water.

RULE V.—*Volumes of heat are carried upwards in the duplicate ratio of the times*; just as volumes of water are carried downwards. Let a pipe be placed over the fire, as in Plate II., Fig. 8, and let it be fifty or a hundred yards high. As the wind and heat can pass through its apertures, it will at once be seen that the heat escapes through the upper orifice, and still more so if the upper part be placed nearly in the perpendicular. An example is also afforded by the flame of a candle, terminating as it does in a point or apex *b*, Fig. 5, and forming a parabolic curve. Water also assumes this form in its descent, but with much less celerity (Fig. 6); which difference causes a difference in the two parabolas. From the foregoing it follows, that,

RULE VI.—*Heat is carried upwards, as water downwards, in a perpendicular line*; just in the same manner as light bodies, in water, for example, pieces of wood, or the bullæ of subtle matter when water is made to boil: in which cases we see these bodies are carried upwards with the same velocity as heavy bodies downwards. Heat mounts also by the same law in the aërial element.

RULE VII.—*Heat may be conveyed both upwards and downwards, but not below the surface.* If the heat enters at *a*, Fig. 7, then owing to its lightness it rises through the passage as far as *b*; it next descends to *d*, and again rises and escapes at *f*; as may be seen in curved chimneys. Heat, therefore, may be conveyed upwards as well as downwards through siphons and curved passages, provided the outlet be above the surface *a*: in the same way as water, which is carried up and down by siphons, and at last runs away, though in the latter case the orifice must be beneath the surface; on which points the reader is referred to the case of the siphon, and to hydraulic experiments in general. But, in the former case, if the outlet be beneath the surface, as at *g*, then the heat will not pass at all through the

upper parts towards the lower; just as water will not run out through the upper part of the siphon. *Vide* Fig. 8, where *ab* is a tube, and *m* the fire. When the tube grows warm, the heat rises towards *b*, but does not descend towards *a*: on the other hand, if water be introduced at *n*, it falls towards *a*, and does not ascend towards *b*. This reciprocal result is owing to the weight and lightness of the respective elements.

Rule VIII.—*Heat escapes through the upper parts, not only in the ratio of the altitude, but also in the ratio of the base.* We find, in Rule IV., that heat escapes in the ratio of the altitudes; but experiments demonstrate that it also escapes in the ratio of the base. Fig. 4 represents the large furnace, in which the iron ore is first melted. It remains closed for ten or twelve days, during which the charcoal becomes intensely hot. At the end of this time, the plates over *mm* are removed, and the heat bursts out with great power, though only in that part where the opening is, and diffuses itself among the charcoal, which in about a quarter of an hour ignites spontaneously, and becomes red hot. In this instance, we may see that the eruption of the heat is precisely in proportion to the apertures of the base; and that when the aperture is large, the eruption of heat is large also, and the ignition proceeds with comparative rapidity. Whence it follows, that if the aperture in the upper part be small, and have much fire beneath it, the fire will break out through the aperture in the ratio of the height and of the orifice, but not in the ratio of the quantity. In Fig. 10, let *ab* and *d* represent the lower parts of two chimneys, equal in height and in their apertures *c* and *e*: if each of them be filled with the same degree of heat, then we maintain that as much heat only will escape through the aperture *c* as through *e*, because heat presses according to its altitude and base; just inversely as water escapes through a lower opening, and the pressure is according to the altitude of the column, and the size of the base. See Pascal and others.

Rule IX.—*Heat exercises a pressure and force on the parts above it;* just as water on the parts below it. This follows from the preceding rule. For if the power of heat increases with the altitude, it follows that the parts above it must be pressed by it, as the parts below are pressed by water. However,

whether the weight increases in the duplicate ratio of the altitude, as in air, or in the simple ratio, as in water, is not yet ascertained. The former point is experimentally presented to us in the great furnace where the iron ore is first smelted; which is filled with burning charcoal, and then covered over with plates, as in Plate II., Fig. 3, where *m* is the furnace, and *nn* the aperture closed by the plates. Now if a small aperture be made in the plate at *a*, the heat will rush out with such violence as to force the dust and some of the charcoal upwards into the air. We infer then that fire, by its native power, seeks the upper regions, and water the lower. And the same conclusion may be drawn from the vast expansive force exerted by fire in all cases of explosion.

Rule X.—*When hot air escapes through a hole, it forms spiral eddies in its lower part;* as water does on its surface, when it issues through a hole. These gyrations and spiral whirls of the air are constantly seen in fire-places; and in the great furnace we have mentioned, the flame breaks forth in whirls, just such as are observed on the surface of water.

Rule XI.—*The eruption of heat is prevented by the external air, unless there be an aperture somewhere else for the air to rush in.* If a large apartment be filled with heat, and there be an opening in one place only, for example, near the roof, then we say, that unless there be an opening in the lower part also, for the air to enter, the heat will not escape through the upper aperture. Let Fig. 1, Plate II., represent the room with the heat in it, and let there be an aperture in the upper part at *b*. Now experience shews that the heat will not escape, unless there be another opening somewhere below, as at *a*, *c*, or *d*. In the same way, if water be contained in the vessel Fig. 2, and there be an opening below at *c* and *d*, but no orifice above, as at *a*, then according to all experiment, not a drop will flow through *c* or *d*.

Rule XII.—*Heat cannot possibly escape at all through the lower parts.* Thus if the planks or beams have chinks between them at the lower part of the room, the heat will not pass out through these, but only through the upper parts: just as water will not run through an opening above its surface, but only through one beneath it. But we have already shewn that the lower aperture assists the escape of the heat through the upper

parts, and *vice versâ*. This is the cause of the draught in particular stoves.

Rule XIII.—*As the particles of heat tend upwards, they are dispersed in the air:* just as water when it falls downwards is converted into vapours. Thus experience shows that vast floods of fire are quickly dispersed in the air, and still more so in water.

Rule XIV.—*As fire ascends, it makes the same sound as water when it descends.* Their *undulations,* and many other circumstances, are likewise similar: all which proves that fire and water agree in their elemental nature, and differ only in point of weight and lightness.

And in what follows it will be seen, that a stream of fire may be as effectually dammed up, and kept for household use, as a stream of water.

A new Construction of Stove.

We will here subjoin a description of a newly-invented stove, that consumes no more wood, coke, or charcoal in eight or ten days, than the common stoves require in one or two; and which is particularly available for use in places where the winter is very severe from year to year, and where fuel is expensive.

EXPERIMENT I.

In large furnaces, where the iron ore is smelted into pigs previous to being hammered, the practice is to heat them with charcoal for some time in advance; as in Fig. 11, where *abef* is a furnace, fourteen or fifteen yards high, and two or three in diameter. Before the work of smelting begins, the furnace is filled to the top with charcoal, and the orifice *ab* closed by iron plates; then a little fire is introduced through an aperture at the bottom about *ef*, and this aperture is immediately closed up. The fire diffuses itself throughout the charcoal, and heats the whole mass to the top; and it is observable that the fire increases among the charcoal by degrees, at the same time penetrating into the stone wall or side of the furnace. Here we have to remark, that, 1. Although the furnace is closed by the iron plates *ab*, and covered on all sides, still the fire or heat diffuses itself throughout the charcoal. 2. And gradually pervades the whole mass, penetrating into the very wall itself. 3. Nor, although covered up, is it put out, but rather increases. 4. This generally takes place in ten or fourteen days, for which length of time the heat is found to increase and continue. 5. And what is more, when, after being shut for twelve days,

the furnace is opened and the plates removed, the lumps of charcoal are found entire and unconsumed, except that they have lost one-tenth of their substance, or, *abcd*, which is the empty space. 6. Nor is any fire discovered in the charcoal, but only an intense heat. 7. The charcoal is perfectly black, in fact, of its original colour. 8. After the orifice *ab* has been opened for about a quarter or half an hour, fire shews itself in the pieces of charcoal that lie at the top, and gradually spreads through the whole mass; this takes place spontaneously, owing to the free exhalation. 9. The charcoal thus spontaneously ignited, is consumed in eight or ten hours. 10. Moreover it is observed, that the heat penetrates the wall to a depth of nearly a foot. 11. The same takes place in these furnaces when wood is substituted for charcoal. 12. We learn then from these data, that a degree of heat may lie in the charcoal, and not be destroyed, although the orifices are closed; that it may in addition diffuse itself through the mass of charcoal, penetrate the wall, and go on increasing for a period varying from twelve to twenty days, with only the trifling consumption of one-tenth part of the fuel employed.

EXPERIMENT II.

It has also been observed, in those furnaces where copper is melted, and mixed with lapis calaminaris to convert it into brass, that the fire will subsist in the charcoal from five to eight days without much consumption of fuel. The construction of this furnace is shewn in Fig. 12, where *cdef* is the firehearth or bottom; *ab* is the aperture or orifice; the part *abcf* is conical; *ed* are openings in the bottom for the air and draught. When this furnace is filled with charcoal, it is observed, that, 1. If the orifice *ab* be open, the charcoal burns with great intensity. 2. The fire is increased in proportion as *ab* is open. 3. If the orifice *ab* be covered with a plate of metal, or stone, the fire at once goes out, and the charcoal becomes black. 4. When the aperture *ab* is completely closed, immediately the charcoal is no longer red hot, but black. 5. Nevertheless, even in this case, a degree of heat continues in it for a period of from five to fourteen days, and without much consumption of fuel. 6. And

after a lapse of six or eight days, when the orifice is again opened, the fire returns spontaneously into the charcoal.

EXPERIMENT III.

If ignited charcoal, whether in the furnace or elsewhere, be covered with heaps of ashes and cinders, it is found that the fire may lie in the charcoal for two or three days; while in the open air it goes out in as many hours.

And in the ruins of houses destroyed by fire; the fire lies hid for three or even four months, as we ourselves have witnessed.

EXPERIMENT IV.

When wood is converted into charcoal by combustion, it is observed that the fire or heat will continue latent without any consumption of substance, for as long a period as forty days, viz., 1. A pile of wood is covered on the sides, and at the top, with branches of trees, clay, and powdered charcoal. 2. Fire is then applied to it at the bottom, and it gradually diffuses itself through the entire mass; small holes being made for the escape of the smoke and steam. 3. But afterwards, when it is converted into charcoal, all these apertures are carefully closed up. 4. Nevertheless, the fire remains in it for forty days. 5. When at last it is opened, the heap is found to be perfectly black, without a single spark of fire. 6. About half an hour afterwards, fire and flame break out spontaneously. This clearly shews that fire may lie concealed, and live in the wood for many days. 7. The same result takes place if the experiment is tried on a small scale.

EXPERIMENT V.

In like manner when an ore is calcined, the mineral stones are piled in a heap, wood is placed under them, and they are covered on all sides with powdered scoriæ and charcoal dust; and although the heap is thus covered over, yet the fire penetrates and spreads throughout it, and in this way the calcination is carried on during a period of from thirty to forty days.

FIG. 13.

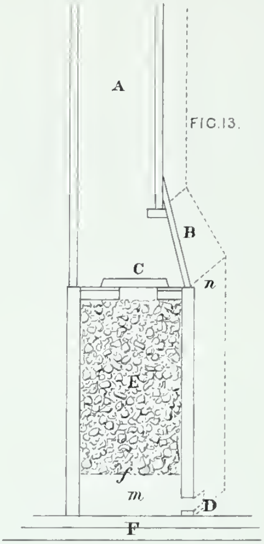


FIG. 14.

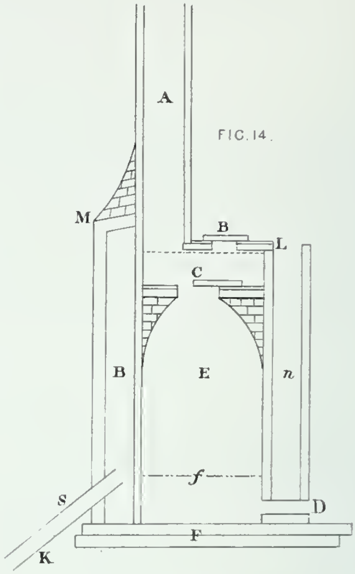


FIG. 15.

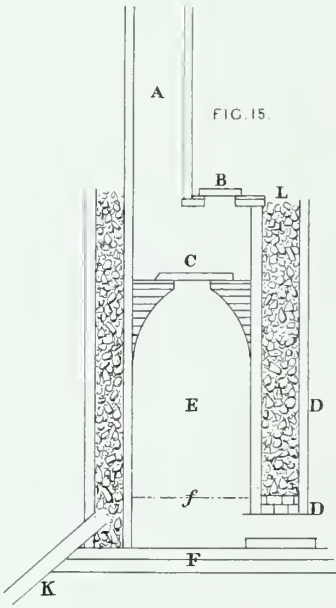


FIG. 16.

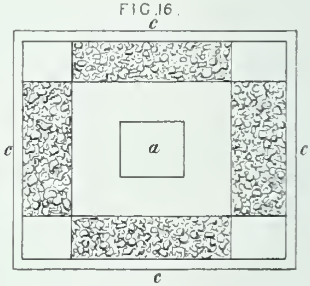
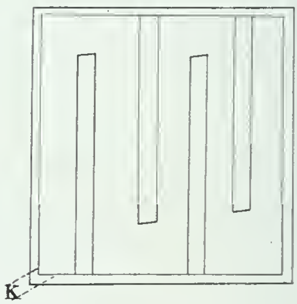


FIG. H.



Hence it appears that fire may remain hidden in wood and charcoal for days and weeks, and a degree of heat be preserved without any consumption of fuel. Guided by these experiments, we will now describe a stove that might be used for household purposes with a great economy of fuel.

The first construction.

The simplest make of our new stove is shewn in Fig. 13, which represents a perpendicular section. 1. D*n* is the outer form or wall, which may be of brick or stone, one brick thick, two and a half or three ells high, and one and a quarter, or one and a half wide: the upper portion is inclined obliquely round *n*, and is provided with a covering or iron plate B, which can be removed and replaced again. A is the highest part, through which the smoke and vapours escape. 2. E is the internal construction, which is a cavity of the size mentioned above; in the upper part there is an aperture, either round or square, one foot in diameter, to which a plate C of stone or iron, as may be preferred, is to be fitted; *f* is an iron grating to support the charcoal or wood used as fuel; *m* is the place for receiving the ashes and lighting the fire; the passage into this part is through the opening D, which can likewise be closed or opened. This is the simplest construction of this kind of stove. 3. When a fire is to be lighted, the space E must be filled with wood and charcoal, resting upon the grating *f*; the fuel is to be introduced through the apertures B and C, but the fire must be introduced in the lower part through D; it will thus ignite the mass of fuel, and as soon as this takes place, the aperture C is to be closed, and D also, if desired; the lighted fire being diminished and to a certain degree extinguished by the closing of these orifices. 4. Hence, according to the experiments mentioned above, the heat will be diffused through the fuel, and will lie concealed, and maintain itself, for several days without much consumption of fuel, until the wall D*n* grows warm, and heat is diffused from it throughout the apartment as from the common stove.

1. If the aperture at C be closed too accurately, so as to

afford no passage for the smoke, it is to be feared that the heat would be entirely extinguished; the orifice at C should therefore be left open to a certain degree, and again closed, if required. 2. If both the apertures D and C be opened, the air will of course pass through, and create a draught, and fire or flame will burst out amongst the fuel; in the same way as in wind furnaces, where the draught is diminished if the upper part be covered, and *vice versâ*. 3. This then is the simplest construction of stove, by which heat may be obtained in a room without much consumption of wood, and be maintained for several days, according to the experiments already described.

The second construction.

An obstacle to the general use of this stove is, that when the heat is kept up, noxious vapours and prejudicial exhalations may emanate from its walls: but this evil may be remedied by the following elegant contrivance, the invention of a French author, who has written a treatise on *The Mechanism of Fire*. 1. Let E, in Fig. 14, be the above-mentioned stove, with arched work within the fire-place *f*, and with its apertures B and C, here placed somewhat differently. 2. Around the stove, another wall is to be built, as at LDMS, separated by the space *n* from the inner wall, so that the stove is double. 3. In the lower part, the pipe K must be brought from the external atmosphere into the cavity or space B and *n*, in which the air circulates, is warmed, and at length escapes through the orifice L. 4. The intermediate space through which the air circulates before it makes its exit, is like Fig. H, whereby the air passes up and down, and becomes considerably heated before it escapes through L. 5. By these means, fresh heat or warm air is continually entering the room instead of the noxious air given out by the first-mentioned stove.

The third construction.

This construction is similar to the preceding, and is represented in Fig. 15, where the intermediate space is filled with small pebbles, metallic scoriæ, or saline substances; from which

the heat will rush out in abundance like a torrent. 2. These stones might also be placed loosely upon each other (in the figure they are only small pebbles), so that the air might flow through them, after having been brought thither from the external atmosphere by the tube K. 3. The horizontal section is shewn in Fig. 16.

Thus we see that fire itself, just like water, may be kept under rule and not suffered to run wastefully away: although if the steam be free, more will escape in two hours, than in eight days when properly checked. Both fire and water, therefore, may be kept for use for a long time by mechanical contrivances. At the next opportunity we shall proceed to describe other sorts of stoves, and principally those for metallurgic works.

END.

A

NEW METHOD

OF

FINDING THE LONGITUDES OF PLACES,

ON LAND, OR AT SEA,

BY

LUNAR OBSERVATIONS.

THE ORIGINAL FIRST PUBLISHED AT AMSTERDAM IN 1721.

A NEW METHOD

OF

FINDING THE LONGITUDES OF PLACES.

§ 1.

The discovery of the longitude, admitted, as it is, to be eminently useful and desirable, has greatly exercised the ingenuity of the scientific world. Nay, it has been a general practice with princes and the authorities in states to request the solution of this problem from their scientific men, and to stimulate their exertions by the inducement of a large reward. The learned, therefore, have hastened to this new Olympic game, and contended together for the proffered reward and honour, in the diligence of their search for the means by which the question could be settled. Nevertheless, up to the present time, no competitor has won the prize. This is chiefly to be attributed to the natural difficulties of the subject, and to the motions of the heavenly bodies, which to our eyes are so irregular; as well as to our imperfect knowledge of mechanics. In other respects, there has been no deficiency of learned men, nor of excellent abilities displayed, wherewith to penetrate the secret, and gratify the desires of the age. For the rest, in attempting what so many have failed in, and taking the problem from the hand of such illustrious predecessors, I am not to be charged with either undue boldness or overweening confidence in my own powers. To the gentle reader I commit my claims, and constitute him the sole judge of my success.

§ 2.

It will first of all be necessary briefly to mention the methods that have been proposed up to the present time; not, however,

with a view to find fault with them, for each plan has some merit, and is at all events supported by the learning of its inventor, but only in order, by comparing and likening many schemes, to enable the reader to judge more correctly of the new method, that we now add to the number of those already published.

Many persons have endeavoured to calculate longitudinal distances by machinery; as, 1. By clocks, or watches, or large pendulums; which as they mark the time with great exactness by their vibrations and motion, so the difference might be ascertained by comparing the time of the sun at noon, with the time as shewn by the above, whence the difference of the longitude at sea might be obtained. But this method was not successful, owing to the imperfection of the mechanism, which could not give an exact measurement of a long period of time, especially as the pendulum was disturbed by the motion of the ship. And the difficulty was aggravated by the varying vibration of the pendulums in different climates and latitudes. Thus the learned world, in praising this method, found it necessary to declare that it was liable to great disadvantages.

2. Others endeavoured to attain the object by measuring the spaces of time, and in general by following the same process as above, with Clepsydras of different sizes, with water-clocks, and sand-glasses; but these means are as little to be depended upon in nice observations of time as those that we have just particularized.

3. Some take notice of the course of the ship, and compare it carefully with its progress, north or south, whereby the longitude towards the east or west ought to be ascertained. But since the speed of the vessel, and the winds and waves vary, the measurement cannot be obtained with sufficient accuracy to prevent the observer from being mistaken in the course of a few days, frequently to the extent of fifty or a hundred miles, as has been proved by experience.

4. Some enquirers, cherishing no expectation of success from mechanics, have proposed that fire-balls should be thrown up from certain insular stations; and as the sailors would see them at night, they would thus know where they were at sea: but the success of this plan was absolutely impossible.

5. Others thought that the longitude might be found by means of the loadstone and the compass, assisted by observations on the course of the ship, and correcting the magnet by ascensions or by the stars; but this plan was useless, for not only does the magnet vary in different latitudes, but it is exceedingly difficult to correct it; and besides, the vessel may vary in its sailing every day.

Some of the learned, perceiving that no assistance could be derived from mechanical science, turned their attention towards the motions of the celestial bodies, and to the larger luminaries. Accordingly, 1. They made use of the solar and lunar eclipses; which being visible over half the globe, and capable of being observed by different persons in different places, afford means for ascertaining the difference of places towards the east or west, by the difference of time. But eclipses seldom take place more than once or twice a year, and hence they are but of small benefit, especially to those who are constantly at sea; although on land the case is otherwise, and almost all the longitudinal distances have been ascertained by them.

2. Others have taken an observation of the moon, when it arrives at the meridian of the observer's place: but it is so difficult to observe the point of the meridian and the arrival of the moon at the point of culmination, that this method must be classed with those which are condemned by their difficulty in practice. For the moon changes its altitude very slowly, both in the diurnal and nocturnal meridian, either ascending or descending: not to mention the difficulty of the parallaxes, which it would require much calculation to clear up. 3. Others prefer observing the moon, when it is in the nonagesimal; that is to say, when the vertical line that passes through it likewise cuts the zodiac or ecliptic at right angles. In this case the difference of the parallax in longitude is got rid of, together with the parallax itself. But as an observation of the moon is still more difficult when it reaches the nonagesimal, than at the meridian, this method is too difficult for practice. 4. Some take note when the moon is at a distance from any given star so many degrees from the ecliptic; but this method is now given up as of no value. 5. Others observe the distance of the moon from the sun; but this plan was not capable of general use,

owing to the difficulty of the observation, and to the necessity of ascertaining the parallaxes in altitude, latitude, and longitude. 6. Others observe the altitude of the moon, and its distance from the stars: but as this method also labours under the same difficulty of the parallax, it cannot be employed by sailors. 7. An ingenious plan is, by the appulse of the moon upon, or its contact with, any given fixed star, and the eclipse of the latter; but it has been abandoned by its most learned author, as the observation of the moon is encumbered with the same difficulties of parallax in altitude, longitude, and latitude. 8. Others have endeavoured to construct instruments to ascertain the latitude and longitude of the moon; but without success; and the idea therefore has been relinquished. 9. Others suggested that the object might be gained, by observing the peculiar libration in the lunar orbit itself; but their expectations were disappointed, owing to the smallness of the libratory motion. 10. Some, for the same purpose, made use of the sun, and the right and oblique ascension thereof; but the difficulties to which this plan is liable may be seen in detail in other works.

11. Seeing that all the methods based on the moon proved useless, some mathematicians turned their attention to the planets, in the hope of finding by their motions some more certain means of ascertaining distances of time and place. But as these bodies move through the zodiac more slowly than the moon, they only point out the time and moments still less clearly than it: and consequently are less useful for discovering the longitude, than a luminary that performs its orbit in the zodiac more rapidly. 12. Others considered that the satellites of the planets would enable them to ascertain the distances, by observing the times when they are concealed by the shadow of their globe or planet, or when they emerge from it. But as they can only be seen with telescopes, and when all is perfectly still and at rest, so the moments of their adumbration cannot be observed on board of ships, which are tossed about by the winds and waves. The methods here mentioned, are deserving of praise, in proportion to the nearness with which they arrive at the end proposed to be attained. But, as we said before, if the desires of the age have not yet been gratified, it is to be

FIG. 1.

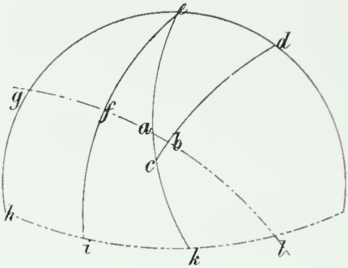


FIG 2.

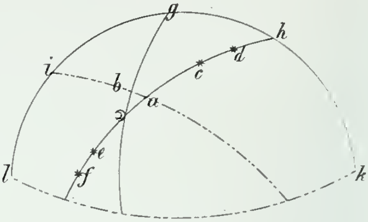


FIG. 3.

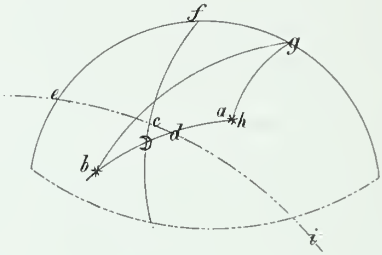


FIG. 4.

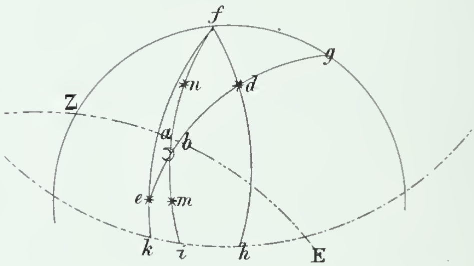
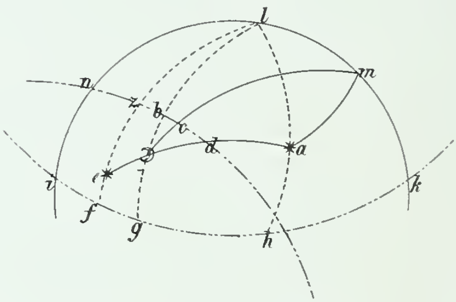


FIG. 5.



ascribed to the motions of the heavenly bodies, which appear so irregular to the senses.

§ 3.

Although the learned world has hitherto sought in vain to discover a sure method of finding the position of given distances, still with the aids of science and industry there is no reason whatever to despair. Although the eminent mathematicians, Kircher and Riccioli, have examined all the inventions mentioned above, and pronounced them all as useless to sailors, yet they say that a method might be based upon the moon's motion, by which the terrestrial longitude might be found, if any means could be furnished for observing the moon without the tedious difficulty of the parallax, the reduction from its apparent to its true position, and the triple difficulty of the latitude. Up to the present time, however, no method has been published that is free from these inconveniences; hence none that could be considered as a genuine solution of the problem, although devised by the greatest scientific abilities of the age. The difficulty will be more clearly perceived on examining Fig. 1. For when the apparent place of the moon in *c* has been ascertained by observation, by its altitude, or by the distance from the neighbouring stars, the real place in *a* must be discovered by working out the solution of numerous triangles. In the first place, the degree of the altitude of the meridian of the place must be investigated; then, the distance of the ecliptic or zodiac from the culminating point of the moon; after which, the angle of the zodiac with the meridian *g*; next, its distance or arc from the nonagesimal *gf*; the complement of the altitude of the nonagesimal *fe*; its distance from the apparent place of the moon in *a*; the angle *a*; which being known, together with the parallax in altitude *ac*, and the right angle *b*, we shall at last obtain the parallax in longitude *ab*, and in latitude *cb*. No less calculation than this is required to obtain the latitude itself, together with the true position of the moon in the heavens, and at length the real place at *a*. There are, in addition, other difficulties of the nodes, zizygies, &c., &c.

§ 4.

It is sufficiently clear from the preceding pages, that none of the above-mentioned methods is fit for nautical purposes, owing to the causes already described: nor indeed can any be brought into practice, except that by means of clocks, if they could be very greatly improved; or that by the moon, if it could be observed without the difficulty of the parallaxes and latitudes; in which the chief source of error consists. As for our own method, which is by the moon, we have solely endeavoured to make the observation and calculation easy; and if we may begin by mentioning its advantages, they will be the following. 1. The apparent place of the moon is obtained by an easy observation, and in some measure at a single glance. 2. Its true place is found by the solution of one right-angled triangle. 3. The knowledge of the latitude is not necessary. 4. The parallax is obtained by the simple observation of the altitude and by the resolution, as already stated, of one triangle, and also, to a certain extent, by a mere inspection. 5. The observation may be taken four, five, or six times, or oftener, during the night. 6. The instruments commonly used by sailors are sufficient for it. 7. It has the appearance and the advantages of an eclipse of the moon. 8. By such observations, ephemerides or almanacks may easily be constructed for facilitating the labours of the observers.

§ 5.

The method itself is as follows. 1. *Take two visible stars, the longitude and latitude of which are known from the tables.* 2. *Observe the time when the moon comes into a line, or into the same arc, with the above-mentioned stars; that is, when the moon* ☽, *in* Fig. 2, *comes into the same line with the stars* ∗ ∗ *ce, or* ∗ ∗ *dc, or* ∗ ∗ *ef.* 3. *From this observation the apparent place of the moon will appear, and afterwards the true place, according to the following methods.*

§ 6.

Here two cases occur. *Firstly.* When two stars are given that are in the same degree of longitude, but differ in latitude: of which many may be found in the tables. *Secondly.* When the two stars differ in longitude as well as latitude. The observation is somewhat easier in the former case than in the latter.

1. *When both the stars are in the same degree of longitude.*

See Fig. 4.

If two stars be taken in the former case, that is, when they have the same degree of longitude, but differ in latitude, it follows, 1. That each star is in its own circle of latitude, and in the same point of the ecliptic; so that if ZE is the zodiac or ecliptic, the two stars *d* and *e* are in the same degree *b* of the ecliptic, but they differ in their latitude *de*. 2. The difference of the latitudes, which is the distance *de*, is obtained from the tables. 3. If, according to the aforesaid method, the moon be observed when it arrives at the same circle with these stars, viz., at ☽, its apparent place is obtained without any observation of the altitude: for it is visibly or apparently in the point *b*, or in the same degree of the ecliptic as the stars. The apparent place having thus been given, the true place is obtained by its reduction from the apparent to the true by means of the parallax, which is found in one of the following ways:

1. *By the altitude of the moon and the two stars.* Let the altitude of these bodies be obtained, viz., *ke*, *i*☽, *hd*, whence the complements *df* and *ef* are given. The angle *d* is known from the three sides *fe*, *fd*, and *ed*; and consequently the subparallactic angle ☽ from the complements of the altitudes ☽*f*, *df*, and the angle *d*. When this angle ☽ is ascertained in the parallactic triangle *a*☽*b*, it, together with the right angle at *b*, and the parallax in altitude *a*☽, will show the parallax in longitude, by subtracting or adding which to the apparent place, the true place of the moon will be obtained at *a*, when the apparent is at *b*. Or,

2. More easily, *by one distance and two altitudes.* The dis-

tance ☽ d, and the altitudes ☽ i and dh are first observed; whence the three sides fd ☽ being given, the subparallactic angle ☽ is obtained; which being known in the parallactic triangle ab ☽, we ascertain the parallax in the longitude ab. Or,

3. Still more easily, *by one altitude and the observation of one angle;* that is, by the altitude of the moon i ☽ and the angle f ☽ d; whence the subparallactic angle a ☽ d is obtained without any calculation, which, together with the right angle in the parallactic triangle, affords the parallax in longitude ab. The angle is obtained more easily in this way than in any other, if the instrument only hangs in a perpendicular position, and is directed to the centre of the moon ☽ and to the star d, whereby the angle a ☽ b is given.

4. A still more easy plan is, *by the simple inspection of the obliquity of the stars.* For if the stars de be situated vertically, so that the circle of altitude passes through the centre of each of them, then the moon will be in its nonagesimal, and free from all parallax in longitude. *Demonstration:* If ∗∗mn are in the same circle of latitude, a right line cuts the ecliptic at a; whence that circle is with the moon in the nonagesimal, and free from the parallax in longitude. 2. If the stars decline towards the right or left, as bd, Fig. 4, then the obliquity may be observed tolerably well by the naked eye; and the parallax is great in proportion as the stars are oblique, but if the obliquity be small, the parallax is small also. 3. If the stars incline towards the right, the parallax is to be subtracted; but if towards the left, it is to be added. *In this manner, by simple inspection, the magnitude of the parallax is shewn, and how much (about) is to be subtracted or added.*

We have here proposed a case when both the stars are in the same degree of longitude, or in the same circle of latitude, of which many may be found in the tables: as in the head of Cassiopea and Lucida Cathedræ, 29° 35′. Two in Andromeda and in the body of Cassiopea, 37° 52′: two in the Triangle, 38° 58′: two in the Fishes, 112° 29′: in the Great Bear and the ship Argo 119°: in the Great Bear and the Crab, 122° 57′: in the Twins, 109° 6′: three in Orion and Hydra, 119° 44′: and many others. When the moon arrives at the circle of these, either above, beneath, or intermediately, the apparent place is

immediately obtained; and from the altitudes, distances, or angles, that is, by simple inspection, the true place is obtained also. Of course therefore, the tedious calculation from the tables for ascertaining the true position of the moon and of its parallaxes, is not necessary, since the whole may be obtained by observation.

2. *When both the stars differ in longitude as well as in latitude.*

See Fig. 5.

In this case also, when the places of the stars differ both in longitude and latitude, it is easy to reduce the moon from the apparent to the true position. Thus in Fig. 5, let the stars *a* and *e* differ in longitude as well as in latitude; let them be stars of the first kind, of which the longitude and latitude are known. Now as this pair of stars is to be made use of, as many others might be, it is a necessary preliminary that from their known longitude and latitude, some astronomer, or the observer himself, should calculate by the rules; 1. The distance *a e*, which is the distance of the stars. 2. The distance of the stars from the zodiac, *ad* and *de*. 3. The angles ☽ *am* and *zde*; which are easily obtained from the known latitude and longitude of the stars. They will then serve for the use of a whole century, and may be put into the almanacks by the astronomer. When these points have been ascertained, the others are easily obtained. Thus when the moon arrives at the circle of the stars *ae*, its parallax and true position are then deduced, either,

1. *From three altitudes*, viz., from the altitude of the moon and of each star. If the altitude of the moon, *g* ☽, be obtained, as well as of the stars, *ef* and *ah*, we ascertain the complements *la* and *le*, with the intermediate distance *ea* already calculated. These three afford us the angle *lae*: whence from the three known data in the triangle *la* ☽, (viz., the complements of altitude *la*, *l* ☽, and the angle at *a*,) the angle *l* ☽ *a* is obtained. Now the angle *bd* ☽ is already known; and hence in the triangle *bd* ☽, from the known angles *d* and ☽ and the parallax in altitude ☽ *b*, the parallax in longitude *db* is found; by subtracting or adding which to the degree of the point *d* (which is known), the true

position *b* of the moon is ascertained. Or it may be obtained more easily,

2. *By one distance and two altitudes.* Thus if the altitudes *ah* and ☽ *g*, and the distance ☽ *a*, are known by observation, from the three data in the triangle *la* ☽, the angle at ☽ is obtained; whence in the triangle *bd* ☽, the angles at ☽ and *d* and the parallax in altitude *b* ☽ are known from the preceding calculation, and we have the distance *db* from the known point *d* to the true position *b*. Or yet more easily,

3. *By one altitude, and an observation of one angle;* that is, by the altitude of the moon *g* ☽ and the angle *l* ☽ *a*. Whence the sub-parallactic angle *b* ☽ *d* is ascertained without any calculation; so that the observer is immediately introduced into the triangle *bd* ☽, in which the angles at ☽ and *d*, with the parallax in altitude, are known from the preceding calculation: whence the distance *db* is obtained, that is, from the point of the zodiac *d* to this place. The Hevelian or any other instrument may be used in taking the observation of the angle. It is only necessary that it should hang perpendicularly, and be directed from the centre of the moon to the star ✱ *a*. Or with still greater facility,

4. *By the simple inspection of the obliquity of the stars.* The angle formed by the intermediate arc between the stars *ae* being known, as well as the angle of its section and of the zodiac at *d*, we likewise have the difference of that angle from a right angle, whether it be 10, 20, or 30 degrees. For example's sake, let it be 30°. Then, when that pair of stars declines 30°, the point *d* is in the nonagesimal; and if the moon be observed in this declination with the stars, it has no parallax in longitude; but the parallax increases in proportion as the point declines from 30° towards the left or right. This may in a measure be seen by the simple inspection of the given angle; as well as whether the parallax is to be added or subtracted.

Hence we see that in this position of the stars, it is not necessary to be acquainted with the apparent place of the moon, but only of the point of the zodiac *d*, which is obtained from the known latitude and longitude of the stars. If ten or fifty pairs are selected, an astronomer would provide us in two days

with the knowledge of the distance of the stars *ae*, the distance from the zodiac *ad*, the point and angle of section in the zodiac, &c. When these data are known, there is no difficulty in ascertaining the remainder, without any tedious calculation of parallax, or of latitude.

§ 7.

In this new method, which I have ventured to lay before the public, there is, 1. A certain appearance of the moon as when eclipsed. For here the moon seems to enter in the same way into a degree of the ecliptic, first with the limb, then with the centre, and afterwards to emerge from the circle, as when she suffers an eclipse. We likewise find that, 2. This method is free from the difficulty of parallax, to be calculated from tables to its apparent place; for the observer is introduced into the parallactic triangle itself by a single observation, which, I believe, has not been done previously. I have consequently given the new name subparallactic to the angle of that triangle. 3. The true position of the moon is obtained by the solution of one triangle, and the simple ratio of the sines; and in some measure by inspection alone. 4. The knowledge of the latitude is unnecessary. 5. This method may be performed in practice with the ordinary instruments used by sailors for taking altitudes and distances. But if the angles are required, it will be necessary to have the Hevelian instrument, or that of Riccioli, or some other adapted for the purpose. 6. The calculation in this plan is easily drawn from tables, for the knowledge of the lunar longitude is alone required, but not of the latitude and parallax. 7. An error of half a degree in the observation of the longitude does not occasion so great an error in the distance of the ocean. A much more considerable error might arise from the tables, if the latitude had likewise to be calculated. 8. When the moon shines, these observations may be taken three, five, or as many as ten times in the course of a night.

§ 8.

To give this method all its advantages for practice, it will be worth the astronomer's while to take from twenty to fifty

pairs of stars, more or less, which are visible in a moonlight night; and to calculate in the tables not only the above angles and distances, but likewise the arrival of the moon at the circles of these registered stars; and if they were adapted to the meridian of the place, and compared with the meridian of the observer, they would give the difference of time, and consequently the difference of longitude towards the east or west. If such almanacks were constructed for whole years, like the lunar almanacks, they might serve for the purposes of navigation; and as it is easy to make them, I will furnish a few specimens towards this end at another time.

§ 9.

The following particulars, however, must likewise be taken into consideration. 1. *The moon and stars, when in a horizontal position, are subject to refraction:* by which they are raised as much as they are depressed by the parallax: therefore when pairs of stars are given, the observations should be instituted in the middle of the heavens: but no greater difficulty will be occasioned by this cause than in the case of the lunar eclipses. 2. *It is comparatively difficult to observe the new moon;* nevertheless the time of its ingress and exit may be ascertained by the immersion and emersion of the limb in the circle; in the same way as in eclipses. Its contact, therefore, may be observed either by the naked eye, or by an extended thread, or by instruments, or in any other way. 3. *Some difficulty may likewise arise as to the observation of the time;* but whether this observation takes place before or after conjunction, is immaterial; any able seaman ought to be able to take the time from the sun at noon, and from the northern stars. 4. But the chief objection that can be produced, is, that no lunar tables, free from error, have yet been published. For when the moon wanders beyond its zizygies, it is liable to so many perturbations or irregular motions, that no certain position of it can be predicted from the tables within fifteen or thirty minutes of the ecliptic, or even more. But furthermore, the inequalities arising from its nodes and its latitudes beyond the zizygies are not important, since the time is only required in

the investigation of the longitude; and hence no greater error can arise from the tables than what may be occasioned in pointing out the moon's place in the ecliptic, which might be corrected by reiterated observations on the same night, or on successive nights. But I have not found that this objection was considered of sufficient weight by any astronomer to prevent him from thinking that the longitudinal distances might still be determined by the moon, provided only that an easy plan were presented; and so I submit this difficulty, if it be really one, like the others, to the judgment of my gentle readers.

§ 10.

I shall very shortly, *Deo volente*, produce, 1. Some longitudinal observations made by this method. 2. A specimen of the almanacks for the use of observers; in which these two cases are set forth; *Firstly*. That the moon may be calculated to the same degree of the ecliptic in which it ought truly to be, when it is in the same line with any two given stars, without any parallax or latitude; because the parallax is obtained by observation. *Secondly*. That the moon may be calculated to the apparent place in the ecliptic, in the same way as in the calculation of the lunar eclipses, together with the parallax. 3. I shall also mention the means, according to this method, of investigating longitudinal differences without requiring a knowledge of the time; viz., by the angles or intermeridianal arcs of the equator.

END.

A

NEW MECHANICAL PLAN

OF

CONSTRUCTING

DOCKS AND DYKES.

A NEW MECHANICAL PLAN,

ETC., ETC.

A New Mechanical Plan of constructing Docks; whereby vessels may be repaired in harbours that are not reached by the tides.

The subject on which we are about to treat, is a new construction of basin or dock, intended to answer the same purpose in the repairing of vessels as the docks in the sea-ports of England and other countries, where the tide ebbs and flows. The benefit of the existing docks is, that a vessel may be received inside them; after which, when the water runs out, the gates are closed; the vessel being left dry; whereby the artificers and carpenters are enabled to work without difficulty on its bottom and sides. Good specimens of such docks exist in several places that have the advantage of a rise and fall of the sea; but hitherto it has been thought impossible to construct them in ports that have no tides. In some such ports, however, it has been attempted; for example, in Denmark, but there the works were abandoned, as involving a fruitless conflict with natural difficulties. Nevertheless, this want of success did not deter the late king of Sweden, Charles XII., of glorious memory, from undertaking a similar work at Carlscrona, where the fleet of the kingdom is stationed, and its naval arsenals are situated; and he committed the execution of it to Christopher Polhem, the most celebrated engineer of his time; with whom the naval architect Scheldon, and the writer of this description, were associated; in order to bring this great work to a fortunate conclusion. It was commenced in the year 1716; and before our heroic monarch lost his life, it was in such a state of for-

wardness that no one could any longer justly doubt of the prosperous termination of the undertaking. As I assisted in this work, and the geometrical admeasurements, together with the disposition of certain matters tending to the more exact attainment of the plan, were intrusted to my care, so I am entitled to speak on the subject with some degree of confidence.

In the first place, the most convenient port for the work was selected, where it appeared that a ship could be placed as near as possible to the shore; and there was a rock very well adapted for the purpose not far from the laboratory or naval arsenal. The place, or dock itself, was excavated in the rock by blasting with gunpowder; which was continued in the usual manner for about three years, until a cavity had been hollowed out of such dimensions as to equal in size the largest vessel; being about two hundred feet in length, twenty in depth, &c. 4. On one side, a well of equal depth was made in the rock (*vide* Fig. 1,* B). This was about three ells distant from the dock itself; and a canal of communication was bored between them for the water to flow through from the dock to the well, and *vice versâ;* the same level being observed.

The dock itself and its internal formation did not require any great skill, but only labour and time sufficient to produce a cavity large enough to hold a vessel. But before the entrance to it could be made accessible to ships, that part of the rock below the level of the sea, which shelved off obliquely under the waves, had also to be removed; and this was a work requiring both skill and industry. Polhem and his coadjutors, therefore, devised an artificial mole or dam, which was constructed above water, and then sunk to the bottom, and thus separated the inner from the outer waters, that is to say, the waters of the dock from those of the sea; in the following manner. 1. Beams and timbers were continued from the rock itself in the form of a circular area, as in Fig. 2. 2. The ends of these timbers rested upon props placed under water, and of which there was a triple row, as in Fig. 2, *cccc*. 3. A circular wooden bridge, running from one side of the dock to the other, was raised upon the props and timbers; and not only could the

* Unfortunately, all the figures relating to this subject are wanting.—*Tr.*

whole body of workmen walk upon this bridge, but the above-mentioned dam was likewise built upon it, above the water. 4. Rams, or posts with four feet, were placed upon this timber, at such a depth as was necessary to reach the bottom of the sea, which was explored by machinery. 5. As the whole dam was constructed above the water, and then let down into it, its lower part was accurately cut to the shape of the bottom of the sea; to effect which a peculiar pendulum with an iron ball was used, as in Fig. 4, whereby the depth of the water and the shape of the bottom were exactly ascertained. 6. When the bottom had thus been investigated, the work of the dam was commenced, the lowest part of which above the water projected to the same length as the difference of the bottom of the sea required, as in Fig. 5. And as the dam was supported by the four-footed posts, the raising was effected by the props mentioned above; between the backs of which and the lower margin of the dam above them, certain timbers were placed which could be afterwards separated from this position. 7. Then the dam was constructed, much as the side of a vessel is generally built, and it was carried to the height required by the depth of the sea. 8. When this was done, three rows of transverse beams were inserted, which strengthened the timber framework, and could be loaded with stones, to sink the dam beneath the water. 9. This wooden dam was also covered with planks on the outer side, fixed in a perpendicular direction, in the same way as they are fastened horizontally to ships. 10. At the lowest margin or edge, some small planks were placed and fastened to the edge of the planking *m* and *n*, Fig. 5, which could be drawn up or down, so that if there should be any aperture at the bottom, it could be closed by this means. The shapes of these is given at Fig. *n*. 11. Moreover, lest any part of the bottom, which was extremely uneven and covered with stones, should happen not to fit closely to the edge of the dam, besides the small planks mentioned above, hides also were bound on and fastened around the dam; and these hides could be drawn up or let down by cords, as at *ooo*, Fig. 5. Hence by this contrivance there was not a spot but could be closed either by the small planks, or by the hides, which were pressed sufficiently closely to the bottom by the superincumbent water. 12. The

dam itself, thus constructed, now stood above the water like a great ship, its greatest height being thirty-six feet, and its diameter sixty: there was an obliquity of 30° of the upper part towards the interior; and this obliquity was formed with the intention, that when the water should press upon it from without, after having been removed from within, it should by its own weight press the dam towards the bottom and keep it fixed: which was afterwards verified by experience. All that part of the wooden dam that stood out beyond the water, hung by ropes fastened from its anterior part to a pair of masts fixed in the earth; but the hinder part was fixed to the rams or four-footed posts, and to three capstans: the whole machine is shewn at Fig. 6. 13. When the dam was to be let down below the water, the timber framework which was made beneath the water, and shown at Fig. 2, was cut away with an axe; so likewise were the rams, and thus the whole machine hung by the ropes mentioned above, and in this way it was lowered into the water. 14. As soon as the dam was let down below the water, the internal timber frameworks already described were loaded with stones, and thus the dam was sunk to the bottom, to which it could be conveniently fitted on account of its peculiar form; and in any place where it did not fit, the small planks and hides were arranged so as to close the apertures. 15. The result was, that when the sand and other matters at the bottom had accumulated around the outer side, or that next the sea, the dam at last, after some weeks, fitted so closely to the bottom, that although the labour had been carried on for some days to no purpose, at length the water within the dam and dock could be entirely exhausted by the pumps, and kept under during the whole time that the work was carried on in that part which was previously beneath the water; and until all that portion of the rock which had been submerged beneath the waves, but which now was laid bare by pumping off the water, could be removed by blasting with gunpowder. 16. This succeeded according to all our wishes, and that part of the rock which was under water was reduced to the same level as the bottom of the dock itself. 17. When this had been effected, the work of the gates was commenced, for which purpose mechanics were brought from Holland: the pumping engine in the well was also begun.

And as the work is thus far finished, and the dock can be closed with its double gates, the dam mentioned above is to be taken away and preserved, and then the newly-constructed naval dock will be available for the repairing of vessels.

The method of using the dock is sufficiently evident. First, the ship is allowed to enter through the open gates, which are afterwards accurately closed; the water is then removed by the pumping engine constructed on a new plan in the neighbouring well, and the ship is left dry, and means are provided by different timber platforms for repairing the sides and bottom, wherever it may be found necessary to do so.

I do not think it requisite to give a long description of the use of this dock, as it is already known to those in particular who employ it for repairing fleets, and have availed themselves of convenient seaports, and of the assistance derived from the rise and fall of the tides. It may be observed, however, that a fleet refitted in this manner would last from ten to twenty years longer than it does when repaired in the usual way, which is by heeling over the ships with machines of different kinds, but this attempt is often useless and unfortunate, and especially answers ill with old vessels. And thus we may say, that an undertaking, till now considered impossible, and altogether new to the world, in Sweden first has been brought to a point, at which no one is justified in doubting of its eventual success, and all this has been achieved under the auspices of our late august monarch.

A new construction of Dam or Mole, for arresting the course of rivers and torrents; with a contrivance whereby it becomes firm and fixed in proportion as the on-coming body of water is large and impetuous: the work being less expensive and more durable than that in present use.

§ 1.

After having described our new dock, it will now be worth while to describe a new kind of dam, for controlling torrents and descending streams of water, and which is so contrived, as to be all the more firm and fixed in proportion to the body and fury of the current; being in fact strengthened and supported by the very pressure of the water; and having the additional advantage of a cheap construction and of great durability. The moles or dams in present use are nothing more than frameworks of timber filled with stones and heavy weights, to resist and check currents of water; but in the spring, when the snows melt, and the swollen streams rise above the dams, the latter are not unfrequently thrown down by the body and pressure of the flood, (increasing, as it does, in force in proportion to its altitude, and to the column of its base,) and the stones themselves, despite their gravity, are carried away headlong in the rushing waters. This disaster, however, is prevented by the new dam of which we are treating, which was invented by our excellent engineer and mechanic, Christopher Polhem, and put to the test of practice eight years ago in a river 30 feet deep, and from 100 to 120 broad, at the village of Lyckeby,

not far from the city of Carlscrona. The late king of Sweden, Charles XII., of glorious memory, confided to Polhem the great work of making the rivers that run between Gothoburg and Norrkoping, and connect the two seas, navigable for ships; of confining and checking by these peculiar dams those rapid rivers, Trollhætta and Motala, celebrated throughout the world for the body and depth of their waters, so as to render them, as we before said, available for the purposes of navigation. Such was the place where these dams were to have been constructed, had that heroic monarch lived; and as, by the royal command, I was associated with Polhem in the work, I am the better qualified for giving a description of it.

§ 2.

1. This dam is constructed of simple planks, but underneath there are beams to strengthen and connect them. 2. Its foot or foundation, if we may use the expression, is a stone wall, that rises no higher from the bottom than suffices to form a plane horizontal to the obliquity of the bottom; as in Fig. 1,* where the height is shewn at BB, and the width at AA: upon this wall the wooden dam is afterwards constructed. 3. The beams and timbers by which the oblique layer of planks is held together and strengthened, are arranged as at *mno*, Fig. 2, with a breadth of four or five feet between each of them: *nnn* are perpendicular, *mmm* are horizontal, and *ooo* are oblique; and the three together form a triangle, in which the perpendicular side is one half of the horizontal side or base. Such triangles are formed at a distance of four or five feet apart. 4. A layer of planks is placed upon these beams, and joined together as exactly as possible. 5. It will be seen, that there is an obliquity of about thirty-five degrees. 6. At the top there is a horizontal plane, as represented in Fig. 3. The dam therefore is constructed simply of triangles at a distance of four or five feet apart, and which act as props; their bases being twice as large as their perpendicular height; and upon these triangles there is a layer of planks; the water pressing upon this planking, and falling headlong over it with a high and rapid torrent.

* These figures are also wanting.—*Tr.*

§ 3.

Thus it is evident that the mole is constructed with small trouble. To shew its utility, let us remark that, 1. The base is twice greater than the perpendicular; in other words, the obliquity of the planking is about 35°; whence it follows, by the properties of water, (which presses equally in every direction in proportion to its height and the column of its base,) that the oblique plane of the layer of planks is pressed by the superincumbent water more towards the bottom than towards the front. Thus, if the pressure towards the front is equal to 1, the pressure towards the bottom will be equal to 2, because the horizontal plane or side of the triangle is twice greater than the perpendicular plane or side. Hence, as the water rises, and as its fury increases, the dam is pressed towards the bottom, and becomes fixed and firm by the very operation of the water itself. On the other hand, were the perpendicular side equal to, or greater* than, the horizontal one, a different result would take place; for the superincumbent water would press equally, or more towards the front part than towards the bottom, and consequently when it rose to a great height, would throw down and sweep away the dam; and still more if it struck against a perpendicular plane, as it does in the present dams. 2. It is also clear that this dam may be made at a very small cost; for it only requires a slight layer of planks, and a few beams as props, at a distance of some feet apart. 3. Our dam is also particularly durable, as the oblique layer of planks is constantly under the water, and not liable to rot. 4. Another point of remarkable convenience is, that a person may walk from one bank of a stream to the other underneath the dam, that is to say, under the planking; and without the least danger see the water falling foaming over his head. If any part of the dam fall in, it may readily be renewed and repaired from the inside; and thus, as we have already stated, it will last for a very considerable period.

* The author has *minus*, but the context evidently shews that it ought to be *majus*.—*Tr.*

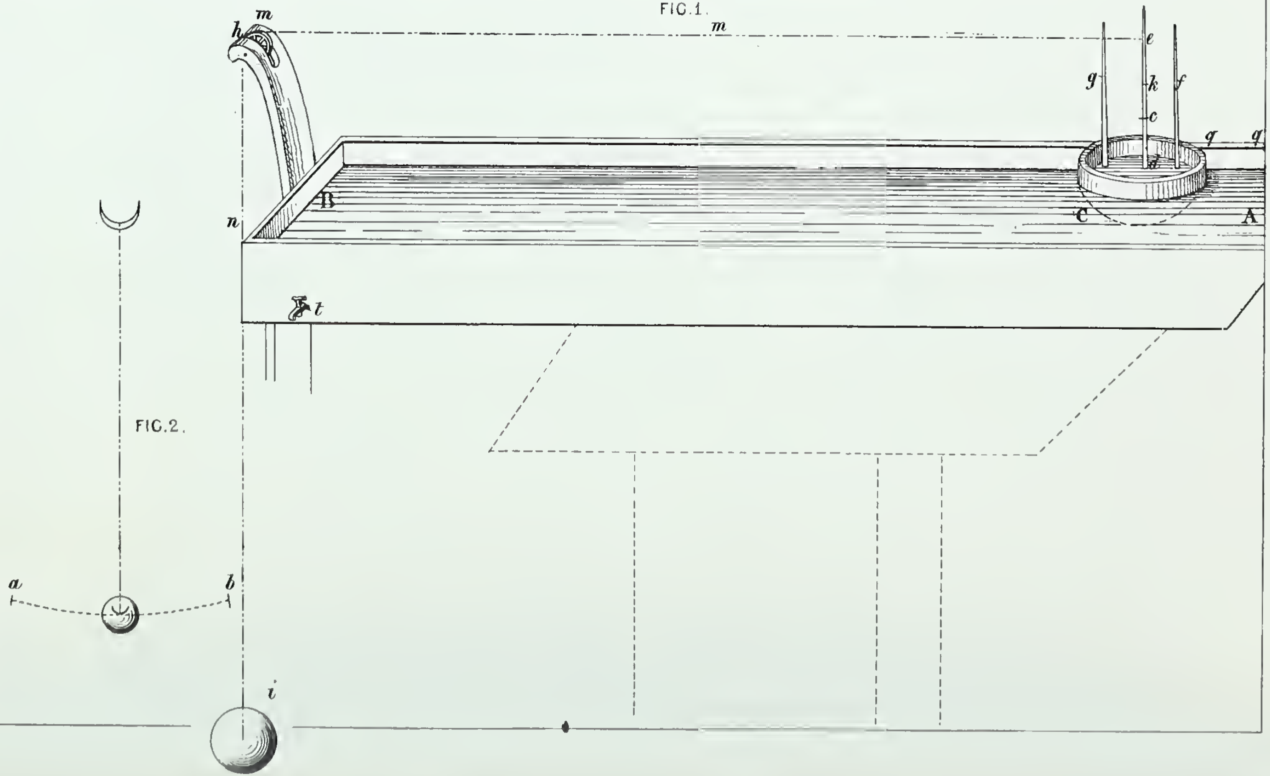


FIG. 1.

FIG. 2.

A mode of discovering the powers of Vessels by the application of mechanical principles.

As an appendix to the foregoing tracts, I will now give a description of a mechanical contrivance for ascertaining the properties of different kinds of ships. At present, it is not accurately known, either by science or any artificial test, which construction of vessels is the best, and the consequence is that there are as many descriptions of vessels, as there are shipbuilders. Many of the qualities of different vessels may, however, be tested in models; and thus it may be found that one construction of ship will be favourable for speed, and not another; that one construction will sail better before the wind than another; that one will sail better nearer the wind than another; and so forth. The art of thus anticipating the sailing powers of vessels from a view of the particulars of the shape in the various cases, will take ages to perfect: still we cannot but admire the industry of the present builders in this department. The hydraulic machine that I am about to describe, is only for investigating the powers of vessels in the model form, and will be especially available for those who happen to possess different models of the kind; see Fig. 1.

AB is a trough, six or eight ells long, one ell wide, and one or two feet in depth, in which models of vessels will conveniently swim. Fix a curved branch with a pulley *h* to this trough, so that it may be raised and lowered at pleasure; *i.e.* raised to *m*, or lowered to *n*, as may be necessary. To meet these conditions it must be attached to the trough in front. A small cord or string passes over the pulley *h*, at one end of which a

ball is fastened at *i*, and the other end is to be attached to the top of the mast, or elsewhere, as at *e*. These preparations made, we are now in a condition to examine ships of different kinds and builds; and,

I. *As to speed.* 1. The models of the ships must be of equal weight; or if any one of them be of less weight than the others, a few pebbles must be put into it to bring it up to equality with them. Fasten the thread at the point *e*; let the height *e*C, and the length *eh* be known. Place the model in the trough AB filled with water. The little ship being now drawn by the ball *i* towards B, the time that it occupies in passing over the distance *eh* is to be observed by the vibration of the pendulum, Fig. 2. This done, another model of equal weight may be substituted, and the packthread tied at the same point of height and distance, viz., *eh*. The time occupied in passing over the same space is then to be noted as before; and so on with five, ten, or any number of models. 2. The direct speed of each kind of vessel, is of course shewn by the time it occupies in its passage over the space *eh*; and the principle would remain unaltered if a large ship, instead of a model, were constructed with the same proportions. In this way then we may observe the difference of various kinds of vessels on mechanical principles.

II. *As to burden.* 1. If the same models are all equally loaded, their relative speed may be discovered by the same means as above. It is clear from experience that one vessel may be more or less loaded than another, and yet lose less speed; this likewise may be ascertained by the foregoing method. 2. If a model that passes over a considerable space in a short time be loaded with a weight, which will bring it down to the speed of the slower vessel, the superiority of the one over the other will be shewn by the difference in the weights.

III. *As to the position of the masts.* 1. If the mast be not placed in the centre of the model, but elsewhere, certain differences will be found to result. 2. If it is first placed in the centre; then in the poop; then in the forecastle; and afterwards between any of these parts, in each of these cases the difference of time required for traversing the space *eh* is to be noted; and by doing this, the most convenient place for the

mast may be discovered in the model. 3. So likewise, if the string is fastened to the fore-mast *g*, or to the mizen-mast *f*. 4. Or if the mast be placed perpendicularly, or inclined either forwards or backwards; whence its difference in speed may be ascertained.

IV. *As to the sails.* 1. If the string be fastened to the mast at *e*, *k*, *c*, or *d*, the power of one sail may be compared with that of another, and we may judge of the power of the different sails. 2. In the same way, if the packthread be attached to the fore or mizen masts at different heights, we shall be enabled to judge of the difference of the sails in power and traction. In this case we must depress the branch *h* and the pulley, so that the packthread may, as required, be brought down horizontally, parallel to the surface of the water.

V. *As to the winds.* If the ball *i* be increased or diminished in weight, or if several other balls be added, we shall then ascertain the power of the winds. As the wind presses on the sails and drives the ship through the waves, so the same will take place, if instead of wind and sail there be the weight *i*, whether large or small.

VI. *As to the ebb and flow of the tide in the bed of rivers.* 1. If the model be left at liberty in the water, without the weight and string, or with an equal weight at *m* and *q*, and if an aperture be opened at *t*, through which the water may flow out and gradually sink in the trough, we may then ascertain how much the model *c* is affected by the subsiding of the water. The same thing occurs in rivers, when the surface of the water is raised or lowered by the tides. 2. There must be a cock at the aperture *t*, which will admit of being opened in different degrees; thus the difference of velocity may be ascertained in different tides, high and low. These experiments should be performed, with models of different kinds, in the manner described above, and the time observed by the vibrations of the pendulum, Fig. 2, which must be of the same length throughout the whole of them.

THE END.

BIOGRAPHICAL NOTICES OF AUTHORS

MENTIONED IN THE PRECEDING TREATISES.

Boerhaave, Hermann, a Dutch physician and chemist, born at Voorhout, near Leyden, in 1668, died in 1738. He was appointed Professor of Medicine, and also of Chemistry and Botany, in the University of Leyden. He was invited to join the Academy of Sciences of Paris, and the Royal Society of London. The work to which Swedenborg refers is the "Institutiones et Experimenta Chemiæ," of which a good English translation was published in 1735 by Timothy Dallowe, M.D. This work is distinguished by its clearness, and exposure of various deceptions which at that period were too often practised. (See *Animal Kingdom*, Vol. II., p. 600, and *Economy of the Animal Kingdom*, Vol. II., p. 365.)

Boyle, Robert, the seventh son of Richard, Earl of Cork, was born at Lismore, in Ireland, in 1626, and died in 1691. He was celebrated for the number, accuracy and importance of his experiments in most branches of natural philosophy, and especially on combustion and the atmosphere. The best edition of his works is that of Dr. Birch, London, 1772, in quarto.

Hevelius, or Hevelke, John, an eminent astronomer, was born at Dantzig in 1611, and died in 1687. As an observer, he was much superior to Tycho Brahe. His industry was very great, and his works are numerous. He improved the quadrant, sextant, and other astronomical instruments; he made most of those which he used, and ground many of his own lenses. A description of his instruments is contained in the first part of his "Machina Cœlestis," published in 1673. As a mark of respect to his talents, Louis the Fourteenth granted him a pension.

Hjærne, or Hiærne, Urban, a physician and natural philosopher, was born in Sweden in 1641, and died in 1724. He travelled in England, France and Germany, and on his return to Sweden was appointed chief physician to the King, and Vice-President of the Royal Council of the Mines. By his influence the Royal Laboratory was established, with the following objects in view:—1. To examine nature attentively, and from the evidence obtained as to the various processes by which her more hidden operations are performed, to lay down certain and incontrovertible principles as a firm foundation for the science of chemistry. 2. To submit to analysis all the substances in nature, in order to discover what they contain, and how they are united together. 3. To enquire into the nature of metals, and means of improving them. 4. To prepare better and more energetic medicines than those in common use; and 5. To encourage all useful discoveries in the arts. Notwithstanding the delay and inconvenience occasioned by the frequent removals of his laboratory,

and by the negligence, idleness, luxury, dissolute morals, ignorance, and occasional ill health of his assistants, of whom he loudly complains, he published his "Acta et Tentamina Chymica" in 1712, and dedicated it to the Royal Society of London, of which he was a member. A Swedish edition of this work appeared previously.

Kircher, Athanasius, a very learned Jesuit, was born at Geysen, near Fulde in Germany, in 1602, died at Rome in 1680. He taught philosophy and the oriental languages in the College of Wurtzburg, and was afterwards appointed Professor of Mathematics at Vienna. He published a great number of works on the physical sciences and mathematics, as well as on languages.

Lemmerius, or Lemery, Nicholas, a French physician and chemist, was born at Rouen, in 1645, and died in 1715. His lectures on chemistry were very numerously attended, and in 1675 he published his "Cours de Chimie," which was immediately translated into Latin, German, English and Spanish. The best edition is that published in quarto by Baron in 1756. Lémery left two sons, who were also distinguished for their chemical talents.

Pascal, Blaise, a very celebrated French mathematician and writer, was born at Clermont, in Auvergne, in 1623, and died at Paris in 1662. He acquired a profound knowledge of mathematics at a very early age; and having turned his attention to the physical sciences, he published in 1647, his "Expériences touchant le Vide," which produced a great sensation in the philosophical world. He also wrote a treatise, On the Equilibrium of Fluids, and another, On the Weight of the Atmosphere. His mathematical works are also of a high character, but he is now best known by his "Pensées," and "Lettres Provinciales." His works were edited by the Abbé Bossu, and published in five volumes, octavo, at the Hague and at Paris in 1779.

Polhem, Polheim, or Polhammer, Christopher, a Swedish engineer, was born at Wisby, in the isle of Gothland, in 1661, and died in 1751. George the First, of England, employed him to execute several important works in the Hanoverian mines. He afterwards returned to Sweden, and was entrusted with several great undertakings, amongst which was the canal of Trolhætta. The dock at Carlscrona, which he executed conjointly with Swedenborg and Scheldon, is still in existence, and is mentioned with great commendation in the "Biographie Universelle," Paris, 1823. He was a member of the Academy of Sciences of Stockholm, and enriched their transactions with many interesting memoirs.

Riccioli, Giovanni Battista, one of the most learned astronomers of his time, was born at Ferrara in 1598, and died in 1671. He entered the order of the Jesuits when he was sixteen years of age. His works are important and numerous; the chief are the "Almagestum Novum, astronomiam veterem novamque complectens," 2 vols. folio, Bologna, 1651; "Astronomia reformata," 2 vols. folio, Bologna, 1665; "Geographiæ et Hydrographiæ reformatæ libri xii.," Bologna, 1661; and "Chronologia reformata et ad certas conclusiones redacta," Bologna, 1669.

INDEX OF SUBJECTS.

Acid. The acid of common salt is a very regular solid triangular particle, excavated so as to correspond to the shape of the interstice between four aqueous particles, 67. There are eight acids in a particle of common salt, 68. The semidiameters of an acid and of an aqueous particle are as 4 to 7, 68; and their weights are as 5 to 18, 69. On distilling common salt, eight particles of acid come over in company with six of water, 70. Some of the extremities of an acid particle are concave, and others are convex, 71. Hence acids are of several kinds; the first or smallest consists of a single particle; the second, of two particles; the third, of five; the fourth, of eight, 71. Acids combine with alkalis, 72. Owing to their shape, the acid particles of salt cannot fix the aqueous particles, but are separated from them by the slightest motion, 74. To remain fluid, the acidity of the liquid cannot exceed the proportion of two particles of acid to one of water, 74. If the acids are in greater proportion, the liquid thickens and forms a corrosive substance, 75. The weight of the acid spirit varies according to the proportions of the acid and aqueous particles, 75. The maximum weight of the liquid acid is to that of water as 14 to 9, 75. The difference of weight indicates the weight of the acid particles, 75. When an acid particle encounters a hard substance having pores, into which its extremities can enter, its point will be driven into the pore by the particles of water, 76. The impelling force is in a right line from behind, 77. The acid particle acts like a minute wedge, 77. The smallest kind of acid can enter a pore whose diameter is to that of a particle of water as 1 to 7, or even less, 77. The second kind of acid has but little power as a menstruum, except in a pore into which water particles can also enter, 78. The third kind exerts its force chiefly on metals with comparatively large pores, 79. Owing to its shape, it retains the aqueous particles more firmly than the preceding kinds, 79. The fourth kind is not adapted to act as a menstruum, but its qualities in some respects are like those of common salt, 79. Acids act differently on different metals, 80. When deprived of water, acids lose their powers, 81; and also when combined with oil, 81. On evaporating an acid spirit of the first kind, owing to the shape of its particles it cannot crystallize, but forms a thick mass, 82. In this mass, the particles of water are transposed from the natural position into the fixed triangular pyramidal, and the number of the acid particles is to that of the water particles as 4 to 1; consequently the mass, as compared with water, weighs as 38 to 17, 82. Its planes cannot be regular, or exactly formed, 82. The acids of the fourth kind may crystallize in the same manner as common salt, owing

to the shape of their particles ; the crystals of salt, however, are right-angled, whilst those of the acid are regular parallelograms with hexagonal bases, 83. Their water particles also occupy different positions, 83, and their proportions differ, 84.

ACID SPIRIT is very mobile, owing to the subtle igneous matter retained between the aqueous particles by the triangular acid particles, 84. It is also colder than common water, and cannot be converted into ice, 85.

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ATOM : see *Particle.*

CALX OF LEAD : see *Lead.*

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Yellow is formed when white and red are mixed together, 132. Thus, if red particles have waters or oils in their interstices, yellow will result, 132.

CRYSTALLIZATION ; *of Acids*, see *Acids. Common Salt* begins to crystallize where there are no longer six aqueous particles to surround a saline particle, 37. The first crystallization takes place when one aqueous particle is surrounded by two of salt, 37. The aqueous particles and the saline particles lie in right lines respectively, 38. The crystal of salt is pellucid (see *Pellucidity)* and lamellar, 38. It forms a pyramidal cube, and its planes are cubic, 38. The particles of water contained in the crystal are arranged in the fixed quadrilateral pyramidal position, 39. Their number in a crystal is to that of the saline particles as 3 to 1, 39. Other kinds of salt can be crystallized with the particles of common salt, but then the crystallization is of a confused character, 39. The plane of the crystal of salt inclines at an angle of 45°, 39. The saline crystals cleave in layers, 41. The water contained in a crystal of common salt weighs to an equal volume of ordinary water as 12 to 11, 42. The salt in a crystal is equal to the excess of the weight of the crystal above 12 to 11, 42. The crystals vary in weight and qualities according to the number of their acid points, 43. Entire particles of salt may crystallize with those which are not entire, 44.

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plane is placed on the joinings of the lower plane, 97. The water particles, and the centres of the nitre particles in the crystal, are in the fixed triangular pyramidal position, 97. The crystal has perpendicular sides, and ends in a point, 98. The perpendicular planes end alternately in aqueous and nitrous particles, 98. Three aqueous particles are required for one of nitre, 98. The crystallization of nitre varies greatly, according to the modes in which it takes place, 98. If saline particles of another kind be mingled with the nitrous, the crystals will vary both in shape and weight, 99. The weight of a perfect crystal of nitre is to that of its bulk of water as 11 to 6, 100.

Dam. A new kind of dam or mole for controlling torrents, 236.

Distillation. A distilling fire causes the saline particles to move centrally, and the aqueous particles to escape in vapour, 60. But the particle of common salt cannot accompany the bulla of vapour, owing to the loss of equilibrium which it occasions, 60. The six aqueous cannot be separated from the saline particle whilst gyrating centrally, unless the triangular points be broken off, 60. These triangular points are the acids, 61 ; and they find a most convenient place between the particles of water on the surface of the bulla of vapour, 60. The equilibrium of the bulla is not destroyed by the acids, because its surface can be equally filled on every side, 61. The number of acids which can accompany the bulla is equal to twice the number of the aqueous particles in it ; and when thus filled, the bulla appears of a red colour, 61. See *Colour*. But if the bullæ vary in size, a white colour is produced, 61. The first product in the distillation of salt is phlegm, or the superficial water of the crystals, 61. Then comes an acid spirit, 61. The whole of the acid particles are not separated by the first distillation, 62. The remainder consists of cubes, 62.

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Heat cannot escape at all through the lower parts, 204. As the particles of heat tend upwards, they are dispersed in the air, 205. As fire ascends, it makes the same sound as water when it descends, and their undulations, and many other phenomena, are similar, 205.

FLUIDITY is chiefly owing to the rotundity of the particles, 19. The fluidity of the particles of common salt in water is owing to the exact harmony between their respective shapes, the saline particles precisely fitting into the intervals between the aqueous, 35, and to the different kinds of matter of which they are composed, 36. To be flüid, the saline particle must be constantly beset by six aqueous particles, 36. The particle of nitre, to be fluid, must be beset by twelve aqueous particles, 92. And the particle of lead requires twenty-nine aqueous particles, 156.

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IGNEOUS MATTER consists of bullular particles, susceptible of dilatation and compression, 86, 199. These particles are small enough to pass through all hard substances, and they may form various bullæ of different sizes, 199. They are exceedingly mobile, owing to their amazing minuteness, 200.

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148. When the salino-plumbous crystals are regular, they are pellucid, and exactly cubic, 149; but if irregular, they are amorphous, not transparent, but like a white powder, owing to the confusion of their particles, 149. See *Colours*. When crystallized by evaporation, the particles are conjoined by the simple application of their sides, 149. If the crystallization be assisted by the water, and made regular, the particles combine in the fixed quadrilateral pyramidal position, and may grow into spires and branches, 150. But if the water be not sufficient, a peculiar shapeless powder is produced, 150. The difference of the crystallization of lead by evaporation and by salts, 150. A mass of lead crystallized in the most regular manner by particles of common salt, weighs to its bulk of water as 5 to 1 nearly, 151. The weight may vary by admixture with other particles, 152. Properties of the particles of lead when combined by sulphurs or oils, 152.

Lead ore is similar to the crystals, as the lead particles are bound together by saline or stony cubes, or by sulphurous particles, 152. The particles are arranged cubically, and form regular planes, 153. The particles of lead may be crystallized by globules in the same manner as by cubes, 153. The weight varies according to the substances by which the lead particles are combined, 154. The colours exhibited by the particles of lead are owing to their irregular mixture with other particles, 155. See *Colours.*

The particles of lead are prevented from uniting, when each is surrounded by twenty-nine aqueous particles, 156. In this case, the water weighs to the lead as 1 to $6\frac{25}{29}$, or the specific gravity of the solution is $5\frac{3}{7}$, 157. The particles of lead are easily liquefied by fire, owing to the ample spaces between them, 157. When melted, lead becomes fluid, like water; and could the globules be separated from the cubes, they would weigh to a volume of water as 14 to 1 nearly, and would resemble mercury, 158. When lead is calcined, its particles are transposed by the fire into bullæ, and thus converted into calx, 159. Certain additional particles are formed by fire, similar to the oily particles in retorts, which alter the nature of the calx, 159. The change of colour in the calx is owing to the changes in the bullæ, and to the admixture of the additional particles, 160. The calx gains in weight, 160; but its specific gravity diminishes, 161. The bullæ are formed by twelve particles of lead, arranged in the fixed quadrilateral pyramidal position, and their diameter, compared to that of a particle of lead, is as 3 to 1, 162, 163. Ceruse weighs to metallic lead as $8\frac{5}{8}$ to $11\frac{1}{2}$; and minium as $8\frac{1}{3}$ to $11\frac{1}{2}$ nearly, 164. When melted, they are resolved into metallic lead, but in diminished weight, and with altered characters, 165. Lead is convertible into glass, in which state the superficial particles are compressed into dodecahedrons, 166.

The *calx* is soluble in menstrua, and remains fluid until its particles are to those of the water as 1 to 87 nearly, 167. When the water is reduced below this proportion, crystallization commences, and a pellicle is formed, 167. The crystals are hexagons, similar to those of nitre, 167. Owing to the form of the bullæ of calx, other particles may adhere to them, 168.

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figures, increased in weight by the accession of new matter from the disintegration of particles of the third kind in the bowels of the earth, 134. If metals be compounds of hard particles of the fourth and third orders, a volume of their particles will weigh to a volume of water as $14\frac{6}{11}$ to 1, 134. This matter is formed into globules equal in size to the water particles, 135, but ten times as heavy, 136. If these globules have hard matter of the third kind in their interstices, they will weigh to the particles of water as $14\frac{41}{88}$ to 1, 136. Saline matter of different kinds may also be filled with hard particles of the third order, 136. The weight of the metallic matter is to that of the saline as $5\frac{1}{4}$ to 1, 136. Compared to a water particle, a metallic acid weighs as 13 to 9 ; a metallic cube as 26 to 9 ; and a particle of metallic oil as 5 to 1 nearly, 138. Saline matters, as acids, fixed alkalis, &c., can adhere to the metallic globules, 138.

NITRE. The particle of nitre consists of a volume of subtle matter, with fourteen acid particles arranged on its surface, 86. They are reduced to an angular and regular position by water particles, 87. Twelve water particles can find room in the spaces between the fourteen acids, 87. The diameter of the enclosed volume of subtle matter is equal to the diameter of a water particle, 87. A particle of nitre weighs to a particle of water as 4 to 1 nearly, 88. It has a bitter taste, owing to the spicula on its surface, 88 ; but as its particle is heavy, it has no odour in water, 89. Nitrous particles are very abundant in nature ; they are generated in plants and vegetables, 89, and in soils and earths ; but not in a sterile soil, 89. Nor where the soil is too wet, or has undergone the action of fire, or is entirely without shelter from the sun's rays or winter's cold, 90. The best soil is that which is under cover, as in old houses, 90. Nitre is also formed in the air, 90, and effloresces from calcareous stones and bricks, 91. It is reproduced in the earth year after year, 91.

Owing to their shape, the particles of nitre will float about in water, 92. Each nitre particle, surrounded by its twelve water particles, forms a *volume of nitre*, which weighs to a single water particle as 16 to 1 nearly, 93. When nitre is dissolved in water, the arrangement of the particles of the latter is changed from the natural position to one nearly approaching the triangular pyramidal, 93. The nitrous particles add but little to the bulk of the water, 93 ; but they drive out the igneous matter from its interstices, and thus render the water very cold, 93. A larger number of particles of nitre than of common salt may find room in water, 93.

The particle of nitre cannot accompany the bulla of vapour into the air, 94. The particles of water, therefore, alone pass off in evaporation, whilst those of the nitre remain behind and crystallize, 94. A pellicle is formed on the surface of the liquid, when crystallization is about to commence, 95. See *Crystallization*. Nitre is much more soluble in water than common salt, 101. See *Solution*. By a distilling heat, nitre yields phlegm and acids. See *Distillation*.

Nitre is calcined by adding sulphur, charcoal, &c., and detonating it, 109 ; but the division which ensues is not the minutest of all, 109.

Nitre is the principal essential salt, 110. It is peculiarly adapted for entering into vegetation, 110, owing to its being composed of water, salt, and subtle fiery matter, and to the form of its particles, 111. Nitre fertilizes land, 112.

OCEAN. A primeval ocean formerly covered the present soil to an immense depth, 3. Proofs of its existence, 4. Its power, 5. It must not be confounded with the deluge of Noah, 6. Mountains of salt and stone, and all saline compounds originated in it, 7, 66. See *Sea*.

OIL. The particles of oil consist of saline ramenta closely arranged round a

volume of subtle fiery matter, 114. See *Ramenta.* Ramenta of various sizes may beset the surface of a single volume of fiery matter, 115. The diameter of an oil particle is equal to that of a water particle, 115. Its weight varies according to the size of these ramenta, 115. The oil particles may be formed in distillation, or by the mutual shocks of the salt in the sea, 115. Also in the earth, and in animal bodies, 116. Oils may be applied to all kinds of salts, and will adhere to them more closely than water, 117. They cannot again be separated except by fire, 117. The fluidity of oil depends on the spherical shape of its particles, 117. By distillation, it is resolved into subtler particles, and into an insipid earthy matter, formed by the denser ramenta, 118. The particles of oil may be converted into bullæ and vapours, like those of water, 119. They are also decomposed spontaneously in course of time, 119. The oleaginous particles combine both with acids and salts, and their properties are mutually altered, 119. They form the basis of various substances, as tallow, wax, asphaltum, camphor, sulphur, &c., and of many of the animal fluids, 120.

Ore of lead: see *Lead.*

Particles. The first or simplest kind of particles are atoms composed of mathematical points; the second kind of particles are formed of particles of the first kind arranged in a hollow sphere; in like manner, particles of the third kind are formed by those of the second arranged in a similar way; and so on in the fourth, fifth, and sixth, 16. The diameters of these respective particles increase in a tenfold ratio, 16. The arrangement of the *crustals*, or particles forming the surface of a larger particle, is triaugular, 17. Each of these kinds of particles contains a hollow space nearly equal to half its bulk, 17. The particles of water are of the sixth kind, 16.

In proportion as particles are smaller, they are better adapted to the central motion; but larger particles are more calculated for local motion, 55. Their axillary gyration is rapid in proportion as they are subtle, 55. Particles of an unequal shape break in their thinnest parts, 55. The particles of salt, when broken, may be reunited by means of water, though not otherwise, 65. The particles of the subtle igneous matter are bullular, and susceptible of dilatation and compression, 86. All particles are transparent, 127. See *Transparency.*

Pellucidity, of a crystal of salt, is owing to the rectilinear arrangement of the saline and aqueous particles, and of the empty spaces, 38.

Position. In the vertical position, the centres of eight particles form a regular cube, 8. Its properties, 9. The three kinds of triangular positions, 9, 10. The fixed triangular pyramidal, 11. The fluid triangular pyramidal, 12. The fixed quadrilateral pyramidal, 12. The fluid quadrilateral pyramidal, 13, called *natural*, because it is the position assumed by the particles of water and other fluids, as well as by the particles of solid bodies when liquefied by fire, 13.

Ramenta, of salt, are the extremely fine and acuminated parts existing at its sides, when first formed at the bottom of the sea, but which are abraded by the least friction, 113. They consist of hard particles of the fourth order, and are cavo-triangular in shape, 113. When they are broken away, the genuine figure of true salt is produced, 113.

Red: see *Colour.*

Salts originate from the disintegration of the particles of water at the bottom of the sea, 3, where their crustal particles are moulded in the interstitial spaces between the waters, 31. Saline matter consists of particles of the fifth and fourth

kinds, 31, 33. The shape of the particle of common salt is exactly similar to the interstitial space between the particles of water, 33. It consists of one cube and eight triangles, 34, 59. Its acidity depends on its triangular points, 34. See *Acid.* It weighs to a particle of water as 25 to 9, 34. The disintegration of twenty-five particles of water produces nine particles of common salt, 35. See *Crystal, Evaporation, Solution.*

The particles of common salt are broken and divided into smaller particles by the least central motion, 56. This central gyration cannot take place without water, 56. In proportion as the angular parts are torn away, the salt loses its saline properties, 57. When all the angular parts are broken off, the remainder is a cubic stoma, 56, which possesses alkaline qualities, 59. The fractured surface is either convex or concave, 57. The particles of salt emit a feeble light when fractured, 58. They may be reunited by water, 65. See *Distillation.*

Sea. Its gradual subsidence towards the north, 6. The particles of water at the bottom of the sea are in the fixed quadrilateral pyramidal position, 28, and are there broken into smaller particles, 29, which afterwards form particles of salt, 33.

Silver, experiments on, 171.

Snow. Its forms are extremely various, 26. It consists of perfectly transparent lamellæ or plates, 131.

Solution of salt in water is difficult, in proportion as the salt is fixed and entire, 44. The saline particles can only be removed in layers, 45. Salt may be dissolved in water, until the number of the aqueous particles is to that of the saline as 20 to 1, 45; consequently $5\frac{1}{2}$ parts of salt are soluble in 16 parts of water, 45. Salts, deprived of some of their points, are soluble in a smaller quantity of water, 46. A solution of salt cannot crystallize, before the number of the aqueous particles is to that of the saline in a less proportion than 9 to 1, 46. By evaporation, the aqueous particles can be dissipated, until only five or six remain for one particle of salt, 47. The crystallization of salt may be submitted to calculation, 47. In a solution of salt, the saline particles slightly change the position of the aqueous particles, 48. When salt is dissolved, the subtle igneous matter flowing between the aqueous globules is dislodged, 49. Salt water is heavier than fresh, and the weight indicates the degree of saltness, 50. The volume of the solution is increased by the aqueous particles in the crystals of salt, but its specific gravity is increased by the saline particles, 51. The increase may be calculated, 51.

The solution of crystallized nitre takes place by layers, 101. The bulk of the water in the solution is increased by as much space as the mass of nitre occupied before it was dissolved, 102. The extra weight of a solution of nitre is owing to the nitre particles contained in the mass, 104. The solution of nitre may go on till the numbers of the aqueous and nitrous particles are as 18 to 1, 104. Therefore 135 parts of water will dissolve 62 parts of crystallized nitre, 104. The difference of weight, between a volume of water and a volume of solution of nitre, is equal to the weight of the particles of nitre; and hence the weight of the crystals of nitre can be calculated, 104. A pellicle forms, and crystallization begins, when the proportions of aqueous and nitrous particles are less than 18 to 1, 105.

Stoves, different kinds of, based on the principles of combustion observed in the great iron furnace, 209.

Transparency belongs to all particles in this world, whether hard or soft, 127. All the elements are transparent, 127. That the particles of salts are transparent, is shewn by the free passage of light through their solutions, 128. Metals also,

when dissolved in chemical menstrua, or converted into glass, are evidently transparent, 128. Stones and earths also are perfectly transparent under the same conditions, 128. Transparency is owing to the regular arrangement of the particles at equal distances, 128 ; for although the particles are transparent, yet if they are arranged irregularly, various colours are produced, 129. See *Colours.*

WATER. Its particles assume the triangular position of the second kind on passing into the state of ice, 10 ; but when liquid, they are arranged in the natural or fluid quadrilateral pyramidal position, 13, 17. Its particles are round, and hollow ; their surface is composed of crustal particles of the fifth kind, whose diameter is one-tenth of that of the particle of water, 16. See *Particles.* The interior space is equal to the space occupied by the crustal particles, 17. The rotundity of the particles of water is the chief cause of its fluidity, 19. They also possess a central motion, 20. And local motion likewise, 20. The undulations of water are circular, owing to the spherical shape of its particles, 21 ; but they would assume some other arrangement, were the particles of any other shape, 22. The phenomena of the pressure of water depend on the sphericity of its particles, and their arrangement in the fluid quadrilateral pyramidal position, 22. Water is cooled by certain salts, 26. When stagnant, it becomes putrid, and passes through various colours, 27.

The particles of water assume the fixed quadrilateral pyramidal position at the bottom of the sea, 28, and are disintegrated there, 29. See *Sea.* The interstices between them form cubes with hollowed sides, 29. These cubic spaces are united by triangular spaces between each layer, 29. See *Interstitial Space.* The disintegration of the aqueous particles gives rise to the formation of salts and other substances, 31. A particle of water may be surrounded and enclosed by two saline particles, 37.

WHITE : see *Colour.*

VOLATILE ALKALINE or URINOUS SALT is formed by saline ramenta (see *Ramenta)* adhering to particles of water, 116.

YELLOW : see *Colour.*

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